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In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

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Reports

Distribution of Strontium and Calcium in Major Vegetable and Fruit Crops and Criteria for Use of Fallout–Contaminated Foods

J. W. Ralls, S. Primbsch, T. R. Guckeen, H. J. Maagdenberg, J. Rinehart, F. C. Lamb, and W. A. Mercer[1]

Vegetable and fruit crops were grown in soil enriched with high levels of strontium nitrate. The normally edible portions of the crops were harvested and sectioned into anatomically distinct portions. The strontium and calcium content was measured by flame spectrophotometry or by photon activation analysis. The results are tabulated to provide an upper limit for radiostrontium content of crops grown in soil heavily contaminated with debris from nuclear fission on a massive scale.

If a massive release of radioactivity derived from the fission of heavy elements ever occurs, it may be necessary to attempt to decontaminate and to use some of the crops that had been exposed to airborne fallout. In subsequent years, the problem will be somewhat different; crops will also be contaminated with strontium-90 and other radionuclides absorbed from the soil through the root system. In order to minimize the ingestion of strontium-90 from such crops, it would be helpful to know the distribution of radiostrontium in specific parts of major food commodities.

This report deals with the problem of radiostrontium in foods grown in exposed soil where internal incorporation of strontium would occur. The study was made using experimental soil which was enriched with stable strontium at levels approaching the saline toxicity point. This experimental design was followed to insure crop samples with strontium levels which could be measured readily and accurately. The actual values obtained serve as an indication of the tendency of various fruits and vegetables to incorporate strontium when grown in soil contaminated at maximum levels. It should be emphasized that crops grown in soils containing micro levels of radioactive strontium would have different absolute and differential levels of radioactivity than those reported here.

For some vegetables and fruits, the maximum uptake of strontium from soil may be so low that the food would be safe for consumption, even from heavily contaminated soil. In other food items, a differential uptake of strontium into distinct parts of vegetables or fruits may render portions of the food safe after removal of the contaminated part.

Addition of the stable strontium in the form of the initially readily soluble nitrate makes its availability for root absorption greater than the predominant oxide and carbonate forms in fallout.

Materials and methods

Vegetable crops (broccoli, spinach, peas, corn, tomatoes, potatoes) were grown in a synthetic soil (UC Mix) *(1)* contained in drained 5-gallon pails. The top 4 inches of the soil contained added strontium nitrate at the rate of 2 grams per kilogram of soil. This level of enrichment represented 830 ppm of strontium in the upper layer of soil at the start of the crop growth period.

Dwarf fruit trees (apple, peach, pear and lemon) were grown in soil contained in large wood tubs. The top 6 inches of synthetic soil was enriched with 10 grams of strontium nitrate per kilogram of soil (4,150 ppm). The tubs containing the fruit trees were flushed three times with large volumes of water to reduce the salt level after signs of saline toxicity were noted. The level of strontium in the soil was measured after 14 months of tree growth and sporadic irrigation. The content of strontium in the soil (on a dry weight basis) at various levels (in 4-inch sections) is tabulated in table 1. The variability of strontium content of soils in different fruit tree containers is due to a nonuniform irrigation schedule for each individual soil container.

---

[1] Research Foundation, National Canners Association, 1950–Sixth Street, Berkeley, Calif. 94710.

Table 1. Vertical distribution of strontium in soil of fruit tree containers [a]

Fruit tree container	Stable strontium content in various soil layers [b] (ppm/dry weight basis)			
	Top layer	Upper layer	Lower layer	Bottom layer
1	Not measured	2,980	2,970	2,720
2	1,240	1,350	1,960	4,710
3	1,100	1,000	1,250	2,080
4	1,430	2,700	2,070	1,350
5	742	1,920	2,480	1,990

[a] Measured after 14 months of tree growth and sporadic irrigation.
[b] Four-inch think sections.

Crop samples were harvested at a time corresponding to the commercial maturity of each commodity. The edible portion of each crop was divided into its major distinct anatomical parts. Each portion was wrapped in plastic foil and stored frozen until analysis for strontium content. The crop samples were placed in tared platinum crucibles and heated in a muffle furnace at 600° C. After about 1 hour, large pieces of ash were broken up to insure complete and rapid ashing. The ashing was continued until a stable white material was obtained.

The ash sample in each crucible was slurried in water and transferred to a 100-ml beaker. Concentrated hydrochloric acid was added until the suspension had a pH of 1 to 2. After the addition of boiling chips, the contents of the beaker were heated and evaporated to a volume of about 20 ml. The suspension was filtered. The filtrate and rinsings were combined and made up to a volume of 50 ml with distilled water.

An aliquot equivalent to 20 grams of fresh sample was transferred to a 50-ml centrifuge tube. When necessary, the aliquot was evaporated to a volume of 10 ml in a boiling water bath. After the addition of four drops of bromothymol blue indicator, the solution was neutralized with 3 N NH_4OH. If necessary, the volume was adjusted to 10 ml with distilled water and 5 ml of 2 N hydrochloric acid added with mixing. The solution was heated to the boiling point and mixed with 10 ml of hot 3 N ammonium oxalate solution. The mixture was neutralized with 3 N ammonium hydroxide and the precipitate separated by centrifugation. The precipitation removed all strontium and calcium along with a small amount of magnesium. All of the barium remained in solution. The precipitate was dissolved in 1 ml of 2 N hydrochloric acid by careful heating over a flame. The solution was poured into a 5-ml porcelain crucible. The centrifuge tube was rinsed with three 0.5-ml portions of 2 N hydrochloric acid. The solution was evaporated to dryness under a heat lamp. The crucible was placed in a muffle furnace and heated to 750° to 800° C. until the oxalate salts were converted to the oxides.

Large sheets of Whatman No. 1 paper were cut to 10 by 7¾-inch size. A thin pencil line was drawn 1 to 1½ inches from one edge along the short dimension. The paper sheets were hung in a chromatography tank containing a 2:2:1 mixture of ethanol-methanol-2 N hydrochloric acid until the solvent ascended the length of the paper. The sheets were removed and thoroughly dried before the sample was applied.

The mixed oxide ash was dissolved in 0.5 ml of 2 N hydrochloric acid. The solution was drawn up into a streaking pipette (Microchemical Specialties, Berkeley, Calif., Model MLB) and applied along the origin line of the washed paper. Heat from a hair dryer was used to reduce drying time between applications. Two 0.2-ml portions of the 2 N hydrochloric acid were used to rinse the crucible and streaking pipette. The rinsings were applied to the paper by streaking the pipette contents along the origin line.

The dry papers were suspended from glass rods in a chromatography tank. The developing solvent mixture was allowed to ascend to within ½ inch of the top of the paper during approximately 2 hours. The papers were removed immediately from the tank and dried.

The paper was hung in a spray chamber and sprayed with a 0.5 percent solution of 8-hydroxyquinoline in methanol-water (3:2) until evenly coated and nearly saturated. After about 10 seconds, the paper was sprayed lightly with concentrated ammonium hydroxide solution. The bands of magnesium, calcium, and strontium complexes were readily seen when viewed under ultraviolet light. While the paper was still damp, pencil lines were drawn between the boundaries of the separated cations.

The individual calcium and strontium bands were cut out of the dry paper and placed in 15 ml porcelain crucibles. The crucibles were put into a cold muffle furnace, the heat control set at the highest setting, and the furnace turned on. The temperature was allowed to increase about 750° to 800° C. and then the furnace was turned off.

The ash was dissolved in 5 ml of 0.5 N hydrochloric acid solution. Dilutions of this solution can be adjusted within the concentration ranges of the standard solutions.

The concentration of strontium and of calcium in the solution was measured by use of a Beckman DU Flame Spectrophotometer using a hydrogen-oxygen burner. A test of the precision and accuracy of the complete analytical procedure was made using standard solutions of calcium chloride and strontium nitrate. The recovery of calcium was 82.7 ± 4.0 percent, and the strontium was 99.5 ± 1.7 percent, both at the 100-ppm level.

Some samples were not available in a large enough quantity to be analyzed by the flame photometric method. The strontium content of these samples was determined by a method of activation analysis developed by the General Atomics Division, General Dynamics Corporation, San Diego, Calif. (*2*). Each sample and a standard were irradiated for 1 hour in a photon field produced by converting a 500 microampere beam of 25-MeV electrons to photons with a tungsten target. These energetic photons produced the radioactive strontium-87m (half-life 2.8 hours) via the strontium-88(γ,n) strontium-87m reaction. The 0.388-MeV gamma rays from the strontium-87m were measured, with a multichannel analyzer, as a function of the strontium-88 originally present in the sample. The results from the determination of calcium and strontium are tabulated in table 2. The values are averages of triplicate determinations on at least six samples from different soil containers.

Discussion

A number of important conclusions can be drawn from the data in table 2. If soils should become heavily contaminated with radioactive fallout, one would expect that the accumulation of radiostrontium in various commodities would be as shown below:

Accumulate least radiostrontium—corn, apple, peach, pear;

Accumulate intermediate amounts of radiostrontium—broccoli, potato;

Accumulate most radiostrontium — lemon, peas, spinach, tomato.

Inspection of table 2 will also provide information for the selection of crops for potential decontamination by modified processing. The high strontium content and the physical nature of the material would make spinach, broccoli, and peas unlikely candidates for decontamination. In fact, it would be unwise to grow these crops until the land to be used had been demonstrated to be free of radioactive strontium.

Lemon and tomato juices could be decontaminated by an ion exchange process. This operation warrants serious consideration due to the important nutritional role these commodities play.

The work of Perkins and Strachon (*3*) on the removal of cesium-137 from potatoes suggests that a similar treatment would reduce strontium-90 contamination. Dubrovina and Belova (*4*) have reported that simple boiling in water will remove 20 percent of the initial strontium content of contaminated potatoes.

The ratio of strontium to calcium in the major edible portion of the commodities tabulated in table 2 is not constant. Therefore, it is not possible to estimate strontium content from the known calcium content of these fruits and vegetables.

Table 2. Strontium and calcium content of vegetable and fruit parts from samples grown in strontium enriched soil and in control soil

Commodity	Strontium content a,b (ppm)		Calcium content a,b (ppm)		Sr/ca ratio for enriched soil
	Control soil	Enriched soil	Control soil	Enriched soil	
Potato:					
Pulp	0.75	7.8	164	192	.041
Peel	< .5	4.6	150	150	.031
Broccoli:					
Buds	.4	7.6	1,380	625	.012
Stalk	.4	4.5	306	240	.019
Leaf	.1	6.4	2,130	1,010	.006
Leaf vein	< .5	6.3	877	1,260	.005
Spinach:					
Leaf	2.6	10.1	624	663	.015
Vein	1.8	4.4	181	171	.026
Stem	1.7	1.0	109	66	.015
Peas:					
Seed	< .5	43.7	211	551	.079
Pod	3.7	126	1,817	1,094	.115
Seed embryo	842	4,000	(c)	(c)	----------
Corn:					
Skin	< .5	< .5	349	52	----------
Milk	< .5	< .5	11	23	----------
Pulp	< .5	< .5	19	70	----------
Tomato:					
Juice	< .5	9.7	54	86	.113
Skin	.5	42	160	240	.175
Pears:					
Flesh	< .5	1.6	14	48	.033
Peel	< .5	10.5	68	270	.039
Core	< .5	5.1	125	51	.100
Seed	(c)	34	(c)	(c)	----------
Apples:					
Flesh	(c)	.5	(c)	7.5	.067
Peel	(c)	12.2	(c)	79	.154
Core	(c)	25.5	(c)	103	.248
Peaches:					
Flesh	(c)	0.74	(c)	55	.013
Peel	(c)	2.9	(c)	319	.009
Pit	(c)	1.3	(c)	220	.006
Lemon:					
Juice	(c)	57	(c)	(c)	----------
Pulp	(c)	321	(c)	(c)	----------
Peel	(c)	362	(c)	(c)	----------

[a] Fresh weight basis.

[b] Assuming that all the strontium is strontium-90, the equivalent hypothetical radioactivity can be calculated from the expression:

$$\text{pCi strontium-90/g calcium} = 1.42\times10^{14}\left(\frac{\text{ppm strontium}}{\text{ppm calcium}}\right)$$

[c] Not measured.

Acknowledgments

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REFERENCES

(1) BAKER, K. F., Editor. The U.C. System for Producing Healthy Container-Grown Plants. University of California. Division of Agricultural Sciences, Berkeley, Calif. (1957).

(2) ANDERSON, G. H. Private communication, November 22, 1965.

(3) PERKINS, H. J., and G. STRACHON. Science 144(3614), 59-60 (1964).

(4) DUBROVINA, Z. V., and O. M. BELOVA. Gigiena i Sanit 29(2):40-43 (1964); Chem Absts 60:15045h (1964).

Aerial Measurement of the Kiwi Transient Nuclear Test[1]

R. D. Coleman and V. E. Andrews[2]

The Los Alamos Scientific Laboratory conducted a Transient Nuclear Test on a KIWI Reactor on January 12, 1965, at the Nuclear Rocket Development Station at Jackass Flats, Nev. During this planned destructive test of a propulsion reactor, the Public Health Service's Southwestern Radiological Health Laboratory conducted a land and aerial offsite radiological surveillance program. The aerial aspects of the laboratory's program included sampling and assay missions along flight patterns through the radioactive cloud formed by the destruction of the reactor. Samples obtained from these aerial missions were analyzed to define various characteristics of the cloud. The aircraft made repeated measurements of peak gamma levels in the cloud. The decrease of peak gamma-ray readings with distance from the site of the experiment was exceptionally rapid. The reduction is attributed to a combination of decay and excellent meteorological diffusion.

To advance technology on conditions during and following a nuclear excursion, a nuclear reactor was purposefully destroyed in Nevada on January 12, 1965 and the power excursion was carefully monitored and documented. This was the first such planned destructive test of a propulsion reactor. It was labeled the Transient Nuclear Test of the Kiwi B4E reactor and was a part of the Rover Flight Safety Program. The test was a joint Atomic Energy Commission-(AEC)-National Aeronautics and Space Administration (NASA) project conducted by the Los Alamos Scientific Laboratory at the NASA Nuclear Rocket Development Station, Jackass Flats, Nev., at 1058 hours (defined herein as "H-hour"). The time of excursion was 2.1 milliseconds on a period of 0.63 milliseconds. The excursion resulted in 3×10^{20} fissions and the peak thermal power was 3.3×10^{6} megawatts.

Data from the excursion will be used to obtain basic reactor shutdown information which can be used to predict theoretically the dynamic behavior of nuclear rocket reactors under a wide range of accident conditions. One major test objective was to determine the release and subsequent movement of effluent from the reactor (*1*).

In conjunction with the planned excursion, the Public Health Service's Southwestern Radiological Health Laboratory conducted surface and aerial radiation surveillance. Two cloud measuring and sampling aircraft were utilized by the Public Health Service to document the aerial release downwind from the reactor.

This report describes the aerial measurement procedures used by the Public Health Service during the surveillance of the Kiwi Transient Nuclear Test. Also presented are the results of particle size determinations and laboratory measurements of the type and amounts of radioactivity in the release.

Equipment

The two aircraft used by the Southwestern Radiological Health Laboratory to monitor the test were Twin Beechcraft, relicensed C-45's obtained from Air Force surplus. Each was equipped with gamma-ray detection devices. One plane was used to measure the height of rise of the atmospheric release and was identified as the cloud-height aircraft. The second plane was equipped to determine the projected area and position of the release and take representative samples of the release composition and characteristics. This aircraft was designated as the sampling plane. Three sampling systems were used in the sampling plane. They were an electrostatic precipitator system, a cryogenic sampling system, and a Casella cascade impactor fitted with an isokinetic intake probe.

---

[1] Presented orally at the Tenth Annual Meeting of the Health Physics Society, June 14–17, 1965, Statler-Hilton Hotel, Los Angeles, Calif.

[2] Chief and assistant chief, Engineering Development Program, Southwestern Radiological Health Laboratory, DHEW, Las Vegas, Nev.

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The electrostatic precipitator was a 3-foot long, 2.8-inch inside diameter tube with an axially mounted wire insulated from the tube. An 18,000 volt potential was maintained between the wire and the tube; the tube was positive with respect to the wire. An 8- by 10-inch, 0.45μ pore-size membrane filter, reinforced with nylon webbing, was placed at the end of the tube to trap any particulates not collected on the tube. Two Bureau of Mines 2306 activated-charcoal cartridges were placed in series behind the filter to collect any reactive gases, mainly iodine. Air was drawn through the assembly by a centrifugal blower. A grab sample of the blower exhaust air was collected in a plastic bag during the peak level of radioactivity and was compressed into an evacuated gas cylinder. The sample flow rate was about 8.6 cfm. In the laboratory, the collected particulate radioactivity was removed by washing the tube with isopropyl alcohol and filtering through a 47-mm diameter, 0.45μ pore-size membrane filter.

In the cryogenic sampling system, the air passed through a 2-inch diameter membrane filter, reinforced with nylon webbing, and through a Bureau of Mines 2306 charcoal cartridge before entering the cryogenic portion. The cryogenic sampler consisted of a series of traps submerged in liquid nitrogen, kept at 10 to 15 psi gage. At this pressure, the boiling point of nitrogen is 82° K or −191° C. The air passed successively through a water trap, a snow trap, and a sampling portion filled with 5A molecular sieve, which collected the inert gases. Air was drawn through the system by a double diaphragm pump and the pump discharged through a dry-gas meter. The initial flow rate was 4 cfm and the average flow rate for the total sample was 3 cfm.

The cascade impactor unit used during the surveillance was the commercially available Casella unit fitted with an isokinetic intake probe.

The gamma-ray detection equipment on the sampling plane consisted of a 3- by 3-inch sodium iodide crystal connected to a portable, single-channel pulse height analyzer using a window of 0 to 2 MeV. The gross gamma-ray output from the analyzer was recorded on a strip chart. Gamma-ray dose rate measurements were made with a high range, portable ionization chamber instrument with a range of 0.05 to 50,000 mR/hr on two logarithmic scales.

The cloud-height plane was equipped with a low-range scintillator monitoring instrument having a range of 0 to 5 mR/hr in six scales for gamma-ray detection and measurement. Output from the scintillator was recorded on a strip chart. An external probe with a filter inside the cabin for particle collection was utilized to confirm cloud presence. Impact pressure on the intake moved air through the filter. In addition, two experimental cloud detection systems were carried in the plane for performance evaluation.

Monitoring methods

On the basis of information received from Air Force cloud tracking aircraft which made early penetrations, a flight path was established ahead of the cloud mass and normal to the projected trajectory of the cloud. This intercept was selected so that a known geographical check point was available on either side, but outside the path of the cloud.

The sampling plane flew the interception pattern at 6,000-feet Mean Sea Level (MSL). To continually reference the release cloud relative to the ground, the strip chart of the gamma-ray detector was marked each time the aircraft was over a check point.

The cloud height plane flew at 500-foot increments in altitude above the sample plane, collecting separate filters at each discrete altitude. These samples were analyzed for gross beta radioactivity and identified as either positive or negative and the height of rise of the release was established as halfway between the altitudes for positive and negative results.

The speed of the cloud was calculated from the time required for the radioactivity to travel from the release point to the intercept path. The distance that the cloud traveled between passes was calculated from the time between

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midpoint of the passes and the cloud speed. Cross-sectional area was calculated for each pass using the measured width and height and assuming an elliptical shape as viewed axially. Cloud volume was then determined by the average-end areas method (2). This method is normally used in determining earth volumes in cut and fill operations in construction. An average cross-section area is determined for each segment of the cloud between two passes by averaging the cross-section areas at the two passes. The volume for that segment is the product of the average cross-section area and the distance of cloud travel between the two passes.

Monitoring results

The aircraft passed through the cloud eleven times along the established path. In the plan view of the cloud (figure 1), the observed width and location of the cloud on each pass were progressively displaced forward and back from the flight path along the cloud axis to show the appearance of the cloud as it passed the flight line on each pass. In figure 1, the cloud is normalized at 1220 hours on the flight path. The cloud required 1 hour and 10 minutes to pass the intercept and, by the treatment described, was 22-miles long. The observed maximum width was 8.4 miles on pass 8 at 1230 hours. The top of the cloud was at 10,500-feet MSL in an area where terrain was 2,500-feet MSL. Positive ground level samples on Highway 95 west of Lathrop Wells documented the presence of the released material at ground level and verified the full 8,000-feet cloud height. Using the "average-end areas" method, the volume which passed the flight path was determined to be 2.4×10^{13} ambient cubic feet.

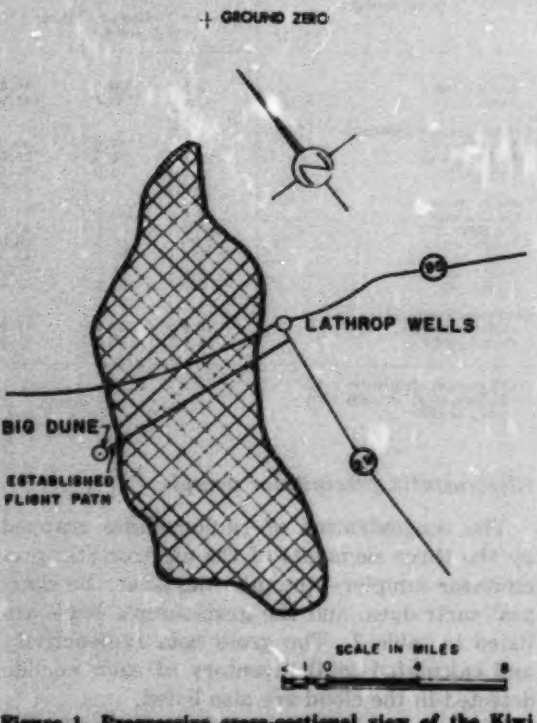

Figure 1. Progressive cross-sectional view of the Kiwi TNT cloud, normalized at 1220 hours along the flight line

Figure 2 shows the maximum exposure observed during each pass versus the time of observation as the cloud passed the flight line. Also indicated are the periods of sampling. The electrostatic precipitator operated during the entire cloud passage. A grab sample was collected during the peak reading of 14 mR/hr at 1207 hours. The cryogenic sampler was stopped after the seventh pass due to nitrogen depletion.

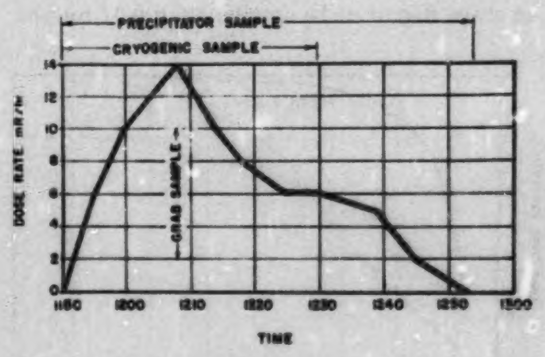

Figure 2. Maximum intensity of gamma-ray activity recorded during successive passes through the Kiwi TNT cloud versus time of reading of maximum intensity

Two other aircraft reported maximum dose rates of 50 R/hr at H + 5 minutes and 100 mR/hr at H + 35 minutes. These readings, with the 14 mR/hr reading at H + 70 minutes, indicate a decrease in dose rate with time (T) by a factor of $T^{-3.2}$.

Particle sizing

A cascade impactor was used to estimate the size range of the airborne particles. Pump limitations made it necessary to use a glass-fiber filter in the fifth stage to obtain design air flow and optical sizing of that stage was not possible; although a flow adjustment error set the flow at 35 liters per minute and optical sizing of the particles on all impaction stages became necessary.

Optical sizing revealed that stages two, three, and four, contained nearly identical particle size distributions; therefore, the data from these three stages were combined for interpretation. In figure 3, the curve representing the cumulative distribution of particles in stages two, three, and four is well separated from the curve representing stage one. In stage one, 73 percent of the particles were larger than 1 micron. In stages two, three, and four, 87 percent of the particles were less than 1 micron. With the system used, the smallest particle that could be sized was 0.47 micron. From the results of stages two, three, and four, it was determined that most, if not all, of the particles on stage five must be smaller than 0.47 micron.

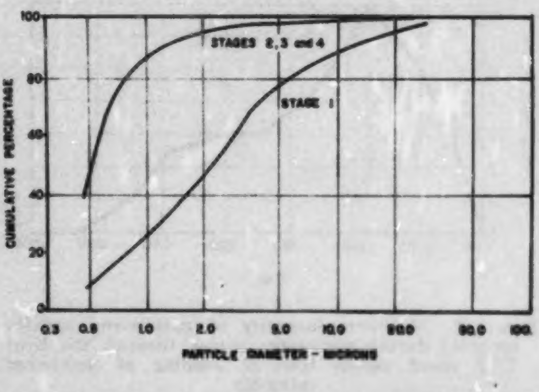

Figure 3. Distribution of particle sizes collected by four stages of a cascade impactor during passes through the Kiwi TNT cloud

The particulates collected on all five stages of the cascade impactor were counted for beta radioactivity and were analyzed by gamma-ray spectroscopy. The radionuclides identified on the five stages were grouped in table 1 according to whether the main precursor was a gaseous, gaseous plus volatile, volatile, or refractory element. The classification of volatile and refractory was made on the basis of boiling points relative to the actual temperature during the reactor excursion.

In table 1, barium, with its xenon precursors, is associated with the smaller particles. Generally, the next two groups, volatile and volatile-gaseous precursors, are associated with particles 0.5 to 2 microns in diameter; the exceptions are the iodines–133, –134, and –135 which are produced during fission and are primarily gaseous products associated with particles <1 micron in diameter. The radionuclides which are refractory or have refractory precursors are associated with the large particles.

Table 1. Percent distribution of radionuclides collected in the cascade impactor during passes through the Transient Nuclear Test cloud

Fission product	Percent activity		
	Stage 1 [a]	Stages 2, 3, and 4 [b]	Stage 5 [c]
Gaseous precursors:			
Barium-139	4.0	50.0	46.0
Barium-140	3.0	56.0	41.0
Volatile-gaseous precursors:			
Strontium-91	7.0	63.0	30.0
Strontium-92	5.0	70.0	25.0
Yttrium-92	11.0	74.0	15.0
Volatile precursors:			
Cerium-143	12.0	59.0	29.0
Tellurium-132	3.0	70.0	27.0
Iodine-131	17.0	57.0	26.0
Iodine-133	6.0	53.0	41.0
Iodine-134	2.0	51.0	47.0
Iodine-135	2.0	41.0	57.0
Refractory precursors:			
Molybdenum-99	40.0	49.0	11.0
Zirconium-97	34.0	53.0	13.0

[a] 73 percent of particles >1μ.
[b] 85 percent of particles <1μ.
[c] 0.47μ or less.

Electrostatic precipitator sample

The concentration of radionuclides trapped by the three segments of the electrostatic precipitator sampler—the tube and filter, the charcoal cartridges, and the grab-sample bag—are listed in table 2. The gross beta radioactivity and calculated total inventory of each nuclide detected in the cloud are also listed.

The gamma-emitting nuclides collected by the system were identified and quantitated by

Table 2. Concentrations of radionuclides collected on the three parts of electrostatic precipitator from the Transient Nuclear Test cloud

Isotope	Concentration (pCi/scf)			Total curies
	Electrostatic precipitator parts			
	Particulate	Charcoal	Grab	
Krypton-85m			280	5.4×10^{3}
Krypton-87			760	1.4×10^{4}
Krypton-88			1,200	2.3×10^{4}
Strontium-89	1.7			33
Strontium-90	0.19			0.4
Strontium-91	680			1.3×10^{4}
Strontium-92	2,950			5.6×10^{4}
Zirconium-niobium-95	13			2.5×10^{2}
Zirconium-97	1,480			2.8×10^{4}
Molybdenum-99	360			6.9×10^{3}
Ruthenium-103	8.2			1.6×10^{2}
Tellurium-132	80			1.5×10^{3}
Iodine-131	25	3.0		5.4×10^{2}
Iodine-133	328	7.3		6.3×10^{3}
Iodine-134	1,190	280		2.8×10^{4}
Iodine-135	625	60		1.3×10^{4}
Xenon-133		1.2	60	1.1×10^{3}
Cesium-138	3,580			6.8×10^{4}
Barium-139	214	4.8		4.2×10^{3}
Barium-140	11			2.1×10^{2}
Cerium-141	7.2			1.4×10^{2}
Cerium-143	310			5.9×10^{3}
Neodymium-147	11			2.1×10^{2}
Neptunium-239	7.0			1.3×10^{2}
Uranium-234	0.48			9.1
Gross beta radioactivity	8.1×10^{4}			1.58×10^{6}

gamma-ray spectroscopy on 200 channels of a 400-channel pulse height analyzer, using photopeak energy and decay rates. Strontium-89 and strontium-90 were quantitated through radiochemistry and beta-particle counting in a low-background, end-window Geiger counter. Uranium was separated and counted by alpha-particle spectroscopy. The backup filter was counted for gross beta radioactivity and decay rate on a 6- by 9-inch gas-flow proportional counter. An aliquot of one-ninth of the alcohol filtrate was evaporated and counted in the 2-inch internal proportional counter.

The concentrations of krypton and xenon in the grab sample were weighted by use of the ratio of average peak cloud intensity to the peak cloud intensity on the pass during which the grab sample was taken. A number of daughter nuclides, such as niobium-97 and iodine-132, were identified on the samples but are not listed since they can be assumed to be present in equilibrium with the parents. Some nuclides, such as the iodines, were collected, at least in part, as the precursors. However, since the precursors could not be quantitated, the activities of the nuclides were calculated as of the midpoint of the collection period.

The particulate gross beta radioactivity collected from the cloud averaged 81,000 pCi/standard cubic foot (scf) [3] at the midtime of collection. Using the volume of the cloud previously determined (2.4 x 10^{13} ambient cubic feet), an extrapolated total of 1.53 x 10^{6} curies were present in the cloud at 1220 hours. Addition of the gaseous isotopes collected on the charcoal and in the grab sample raised the cloud total to 1.58 x 10^{6} curies.

Most of the gross beta particulate radioactivity decayed at the rate of $T^{-1.09}$. The two exceptions were the activities collected by the backup 8- by 10-inch membrane filter, which followed the precipitator tube and contained 8 percent of the particulate radioactivity, and the alcohol soluble particulates from the precipitator tube which contained 2 percent of the particulate gross beta radioactivity; both decayed at the rate of $T^{-1.13}$

The solubilities of the radionuclides collected on the electrostatic precipitator were investigated using isopropyl alcohol, 8N nitric acid, and distilled water. The precipitator tube was washed with alcohol to remove the collected particulates and the solution was passed through a membrane filter. After an initial gross beta count on the filter, it was divided into quarters and each portion was again counted for beta activity to determine the fraction of the total radioactivity on each portion. One portion was followed for beta particle and gamma-ray decay, another was dissolved in nitric acid and filtered, a third was washed in water, which was filtered, and the fourth portion was lost in process. From the results of gamma-ray spectroscopy on the fractions, it was possible to determine the percentage of each nuclide which was not soluble in each of the three agents—alcohol, water, and nitric acid. These results are given in table 3. Although other forms of these nuclides were not excluded by these solubility tests, the respective behaviors were consistent with behavior predicted for elemental or oxide forms of the isotopes reported. The results for iodine-131 indicate that it was collected and separated mainly as the tellurium precursor.

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[3] Standard conditions used were 0°C. and 760-mm Hg.

Table 3. Solubilities of radionuclides collected in the electrostatic precipitator from the Transient Nuclear Test cloud

Isotope	Percent insoluble		
	Alcohol	H_2O	8$\underline{N}$ HNO_3
Strontium-91, -92	95	75	75
Zirconium-95, -97	100	100	75
Molybdenum-99	100	100	95
Tellurium-132	95	100	70
Iodine-131	100	100	80
Iodine-133	90	90	60
Iodine-135	30	75	100
Cerium-141	95	100	100
Cerium-143	100	100	80

Cryogenic sampler

The type and quantity of nuclides collected on the three parts of the cryogenic sampler (the filter, charcoal cartridge, and cold trap) plus the calculated total quantity of each nuclide in the cloud at the midpoint of collection are presented in table 4. All values were adjusted, using the ratio of the average of the peak dose rates on each pass through the cloud during operation of the cryogenic sampler to the average of the peak dose rates on each pass through the cloud during cloud passage, to obtain the average concentration and quantity of nuclides in the cloud.

Beta-particle and gamma-ray analyses were performed on the prefilter, and gamma-ray analysis was made of the charcoal cartridge as in the case of the electrostatic precipitator. Gases were removed from the cold trap and separated using carrier gases on a specially designed system which combines the features of gas chromatography and low-temperature distillation. The resultant gases, which had been separated by element were counted for beta radioactivity in thin-walled, gas envelope Geiger tubes. Isotopic abundances were determined by counting a portion of the gas in glass flasks on a 400-channel pulse height analyzer.

As reflected in table 4, an unusually large portion of the radioactivity was collected on the charcoal cartridge. The anomaly was due to a hole that had developed in the filter during sampling but which was not discovered until the cryogenic sampler intake probe was dismantled after sampling.

Table 4. Concentrations of radionuclides collected in the cryogenic sampler from the Transient Nuclear Test cloud

Isotope	Concentration (pCi/scf)			Total curies
	Cryogenic sampler parts			
	Filter	Charcoal	Trap	
Krypton-85m	....	....	290	5.6×10^3
Krypton-87	....	....	780	1.5×10^4
Krypton-88	....	....	1,200	2.3×10^4
Strontium-91	200	48	....	3.3×10^3
Strontium-92	520	130	....	1.3×10^4
Zirconium-niobium-95	1.7	1.0	....	52
Zirconium-97	210	190	....	7.6×10^3
Molybdenum-99	75	67	....	2.7×10^3
Ruthenium-103	1.3	1.5	....	53
Tellurium-132	47	4.2	....	9.4×10^2
Iodine-131	5.8	1.9	....	1.5×10^2
Iodine-133	230	42	....	5.2×10^3
Iodine-134	890	86	....	1.9×10^4
Iodine-135	86	71	....	3.0×10^3
Xenon-135	....	47	67	2.2×10^3
Barium-139	1,200	38	....	2.3×10^4
Barium-140	10	....	....	2.0×10^2
Cerium-141	0.94	....	....	18
Cerium-143	64	....	....	1.3×10^3
Neodymium-147	0.78	....	....	15
Gross beta radioactivity	1.2×10^4	....	....	2.8×10^5

The gross beta-particle concentration as determined from the filter was 1.2 x 10^4 pCi/scf. Adding the nuclides on the charcoal cartridge and cold trap, the total radioactivity detected in the cloud was 2.8 x 10^5 curies at 1220 hours. The gross beta radioactivity on the filter decayed at the rate of $T^{-1.08}$.

Discussion

Table 5 compares the total quantity of each nuclide detected by two sampling systems—the electrostatic precipitator and the cryogenic sampler—with the total quantity expected at H + 1.12 hours (1210 hours) from 3 x 10^{20} fissions, using the tables of Bolles and Ballou (*3*).

A comparison of the results of the cryogenic sampling system with those of the precipitator system indicated that, in general, the concentrations of individual nuclides and the total radioactivity levels in the cloud detected by the cryogenic system were about one-fourth those detected by the precipitator. Conversely, for 12 of 20 nuclides (table 5) the precipitator collected approximately 4 times more radioactivity per unit of sample than the cryogenic system.

Table 5. Comparison of the total quantities of radionuclides as determined from the precipitator and the cryogenic sampling system versus total amount expected from 3 x 10^{20} fissions at collection time

Isotope	Precipitator (curies)	Cryogenic (curies)	Expected (curies)
Krypton-85m	5.7×10^{5}	5.6×10^{5}	3.2×10^{5}
Krypton-87	4.4×10^{5}	1.5×10^{6}	1.8×10^{6}
Krypton-88	2.3×10^{6}	2.3×10^{6}	1.6×10^{6}
Strontium-89	32	----------	47
Strontium-90	0.4	----------	0.46
Strontium-91	1.3×10^{4}	3.3×10^{5}	7.9×10^{3}
Strontium-92	5.6×10^{4}	1.3×10^{6}	2.4×10^{4}
Zirconium-niobium-95	2.3×10^{2}	58	[a] 61
Zirconium-97	2.8×10^{4}	7.0×10^{3}	5.4×10^{3}
Molybdenum-99	6.9×10^{3}	2.7×10^{3}	1.3×10^{3}
Ruthenium-103	1.6×10^{2}	53	56
Tellurium-132	1.5×10^{3}	9.4×10^{2}	7.8×10^{2}
Iodine-131	5.4×10^{2}	1.5×10^{2}	[a] 1.3×10^{2}
Iodine-133	[a] 6.3×10^{3}	5.3×10^{3}	[a] 2.7×10^{3}
Iodine-134	2.8×10^{4}	1.9×10^{4}	5.2×10^{4}
Iodine-135	1.2×10^{4}	3.0×10^{3}	1.2×10^{4}
Xenon-135	1.1×10^{3}	2.2×10^{3}	1.4×10^{3}
Cesium-138	6.8×10^{4}	----------	6.4×10^{4}
Barium-139	[b] 4.2×10^{3}	2.3×10^{4}	4.5×10^{3}
Barium-140	2.1×10^{2}	2.0×10^{2}	2.1×10^{2}
Cerium-141	1.4×10^{2}	18	[a] 18
Cerium-143	5.9×10^{2}	1.2×10^{2}	2.4×10^{2}
Neodymium-147	2.1×10^{2}	15	1.6×10^{2}
Neptunium-239	1.3×10^{3}	----------	----------
Uranium-234	0.1	----------	----------

[a] These values were extrapolated from the amount predicated for the time of count because they had not reached their maximum activity at the time of collection.

[b] This value for barium-139 too low, see text.

Exceptions were the kryptons, tellurium–132, iodine–133 and –134, xenon–135, and barium–140 which were about equal and barium–139 which was much higher for the cryogenic sampler.

Although it would seem that barium–139 must have been collected on the precipitator tube, it could not be identified on samples from that portion, but was found on the backup filter and charcoal. The difference in the values for neodymium–147 and cerium–141 is most likely due to poor counting statistics at the high background end of the gamma-ray spectrum.

The most likely explanation for the differences between the isotopic and gross beta-particle results obtained from the two sampling systems was the hole discovered in the cryogenic prefilter. Since the charcoal cartridge could not efficiently collect particulates, these passed on to the cryogenic trap, which was not analyzed for radioactivity other than for those gases which could be removed from the molecular sieve. This would be consistent with the observed close agreement of the radioactivity levels of the kryptons (table 5). The iodine–135 collected on the molecular sieve would also have approximately doubled the xenon–135 present during the time between collection and analysis; this would account for the larger quantity of xenon–135 detected on the cryogenic sampler.

On the basis of these interpretations, the most reliable figures for the quantities of nuclides except for barium–139, were those obtained from the electrostatic precipitator system.

A portion of the fuel cladding contained niobium which produced zirconium–97 by neutron activation. This produced a higher value for zirconium–97 than that expected from fission alone. Excluding this isotope and cerium–141, the inventories, as determined from the electrostatic precipitator system, for thirteen isotopes averaged 2.2 times the total expected. At least two possibilities could cause this: (1) a nonrepresentative sample or (2) an error in cloud volume.

As it is impossible to determine the degree to which the sample is representative, sources of error in cloud volume measurement were investigated. Cloud width and thickness were direct measurements and any errors therein should be relatively small. This left the cloud length as the major possible source of error.

Investigation of wind speeds in the area at every 1,000 feet in altitude showed that during the sampling period winds from ground level to the sampling altitude decreased to nearly one-half their speed at the start of the sampling period. This would indicate that the calculated cloud volume was approximately twice as large as it should have been and that the inventories shown are twice the actual values.

The quantity of cerium–141 is still far higher than would be expected. It is possible that this and portions of the other longer-lived isotopes were in the reactor core from previous low-level operations.

Under normal surveillance conditions, an error of a factor of two in the total inventory would be acceptable. However, on the basis of these results, flight operations have been modified to provide confirmation of cloud speed and length during sampling.

Summary

Immediately after the Kiwi Transient Nuclear Test occurred in Nevada on January 12, 1965, two specially equipped aircraft from the PHS Southwestern Radiological Health Laboratory made eleven passes through the effluent from the reactor. Using the on-board sampling equipment, 25 radionuclides were detected: krypton–85m, –87, and –88; strontium–89, –90, –91, and –92; zirconium-niobium–95; zirconium–97; molybdenum–99; ruthenium–103; tellurium–132; iodine–131, –133, –134, and –135; xenon–135; cesium–138; barium–139 and –140; cerium–141 and –143; neodymium–147; neptunium–239; and uranium–234. These nuclides were collected by the use of two different sampling systems—an electrostatic precipitator system and a cryogenic sampler. A third system, a cascade impactor, was used to determine the range and quantity of particle sizes in the cloud. The three systems were used because each one had a preferential efficiency for collecting and trapping different components of the cloud.

After interpreting the data and analyzing the systems, it was determined that the most reliable data on the quantities of nuclides in the cloud were those obtained from the electrostatic precipitator systems. One reason was that the cryogenic system prefilter partially ruptured during sampling. The amounts of radioactivity calculated from the results of the precipitator sampling system ranged from 0.4 curies of strontium–90 to 6.8×10^4 curies of cesium–138. It was determined that the volume of the cloud was 2.4×10^{12} cubic feet and that the total amount of gross beta radioactivity in the cloud was 1.6×10^6 curies; although, due to a change in wind speeds these values may be a factor of 2 too large.

The particle sizes detected in the cloud by the cascade impactor ranged from less than 0.5 to 30 microns. Combining the two "stage" categories of the cascade impactor, the percent distribution of the various particle sizes which could be optically sized was: 28 percent of the particles were less than 0.5μ in diameter; 30 percent were 0.5 to 1μ; and 12 percent were 5 to 30μ. Therefore, most of the particles which could be optically sized ranged in size from 0.5 to 5 microns.

Conclusions

The equipment and techniques presented made it possible to collect data and samples which were used to delineate the radioactive release from the Kiwi Transient Nuclear Test and to quantitate the gross and isotopic radioactivity in the release. With the exception of the error due to the change in wind speed the method of using a single flight path, repeatedly flown during cloud passage, offers a relatively efficient method for labeling and tracking aerial masses. This error is being reduced by new techniques to determine cloud speed during sampling.

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. "Kiwi-TNT" reactor safety test set at rocket station in Nevada. Joint AEC-NASA announcement H–1, U.S. Atomic Energy Commission, Washington, D.C., and Space Nuclear Propulsion Office, Jackass Flats, Nev. (January 4, 1965), p. 3.

(*2*) RAYNER, W. H. and M. O. SCHMIDT. Elementary surveying, 3rd Edition (1955), p. 163.

(*3*) BOLLES, R. C. and N. E. BALLOU. Calculated activities of U^{235} fission products. Research and Development Rep USNRDL 456; NS081–001 (August 30, 1956).

Summary of Population Exposure to X Rays in the United States, 1964

Population Studies Program [1]
National Center for Radiological Health

A summary of the highlights of *Population Exposure to X-Rays, U.S., 1964. A Report on the Public Health Service X-Ray Exposure Study*, Public Health Service Publication No. 1519 is presented. It is estimated that 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits. The estimated annual dental X-ray rate declined from 27.4 per 100 persons in 1961 to 26.8 in 1964. The estimated annual rate of medical X-ray visits increased from 47.9 per 100 persons in 1961 to 49.8 in 1964. Of the 173 million X-ray examinations or procedures performed during these visits, 105 million were radiographic, 54 million dental, 10.5 million fluoroscopic, and 3.5 million X-ray therapy. The estimated number of X-ray films taken were 506 million.

The significance of X-ray exposure to a population became evident in early studies made to determine the magnitude of radiation resulting from nuclear weapons testing programs. To date, estimates of exposure to medical and dental X radiation have been available only on selected groups and could not be applied to the general population with any reasonable degree of certainty. The X-ray Exposure Study was undertaken to obtain information on the X-ray experience of a representative sample of the U.S. population in order to estimate X-ray exposure and dose for the general population.

In 1961, the National Center for Health Statistics in cooperation with the National Center for Radiological Health, collected information on the medical and dental X-ray experience for a representative sample of the civilian noninstitutional population residing in the United States (*1*). This survey demonstrated the feasibility of collecting X-ray visit data by household interviews. The "Field Trial of a System to Obtain Data on Population Exposure to X-rays" (*2*) describes the preliminary test of a complete reporting system including household interviews, facility contact by questionnaire, and the use of film packs as a corroborating vehicle on reported technical factors, as well as beam size and alignment. Based on this field trial, it was concluded that the X-ray Exposure Study would provide estimates of population exposure to X rays and that data compatible with university research in dose model development could be obtained.

The following is a summary of selected information from *Population Exposure to X-rays, U.S. 1964. A Report on the Public Health Service X-ray Exposure Study*. Public Health Service Publication No. 1519. A complete report of the methods and procedures used may be found in that document.

The study had two major phases: (1) the household interview survey from which the X-ray experience of the population was obtained, and (2) a followup by mail to the place where an X-ray visit was reported in the household survey. The facility was requested to provide information on the equipment used, type of examination, machine settings, and to expose an enclosed film pack replicating the first exposure recorded on the questionnaire. The household interview phase provided data which could be compared with the 1961 visit data together with the socioeconomic and demographic characteristics of the population surveyed. The facility followup phase provided technical information on examinations and procedures and films or exposures.

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[1] Prepared by Mrs. Myrtle C. Sydenstricker, Public Health analyst, Population Exposure Studies, Population Studies Program, National Center for Radiological Health, Rockville, Md.

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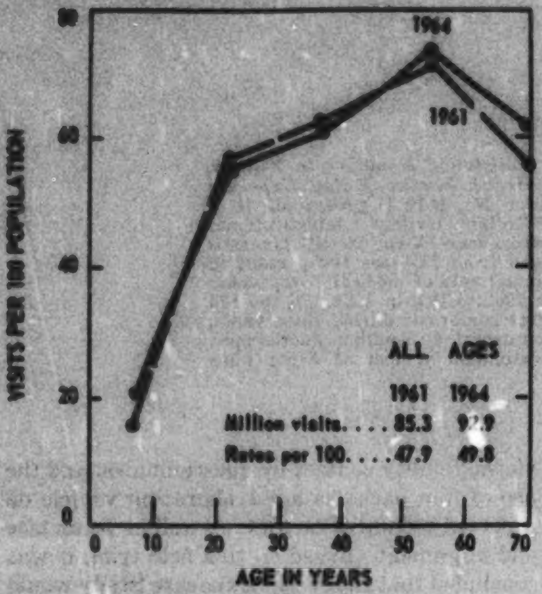

Figure 1. Estimated annual rate of medical X-ray visits by age, 1961 and 1964

An estimated 108 million, or 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits in 1964. These visits were estimated to be 93 million medical and 50 million dental. Between 1961 and 1964, the annual number of medical X-ray visits increased by 8 percent and, in terms of the annual rate of visits per 100 population, from 47.9 visits in 1961 to 49.8 in 1964. The increase occurred among children under 15 and among older adults particularly those 65 years and over (figure 1). The annual dental X-ray visit rate declined from 27.4 visits per 100 persons in 1961 to 26.8 per 100 in 1964.

The estimated annual X-ray experience of the U.S. population is shown in figure 2 for visits, examination and procedures, and films or exposures by type of X-ray visit (about 12 million persons had more than one category of X-ray procedure). An estimate of persons X-rayed during medical and dental visits according to geographic region and sex (*5*) is presented in figures 3 and 4.

The higher annual rate of medical X-ray visits in the West may be due to the greater percent of visits to physicians' offices in this region, 33 percent in contrast to 23 or 24 percent in other regions. This finding is consistent

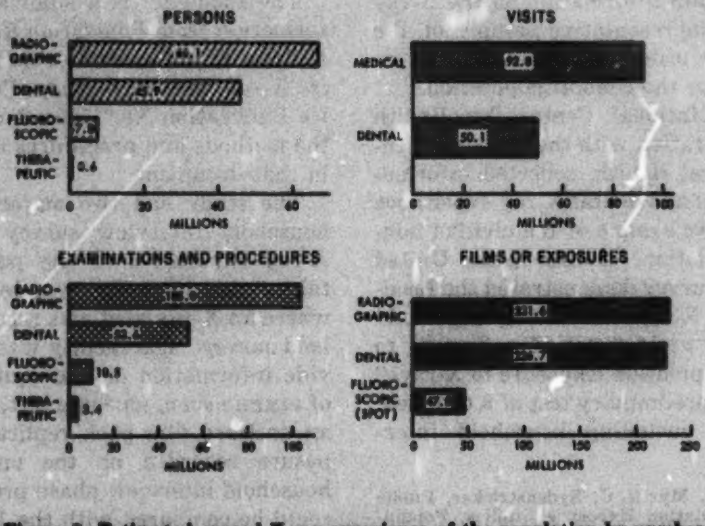

Figure 2. Estimated annual X-ray experience of the population by number of persons, visits, examinations and procedures, films or exposures, 1964

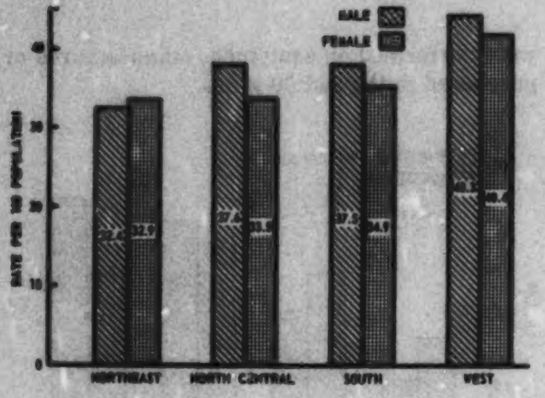

Figure 3. Estimated annual rate of medical X-ray visits (by region and sex)

with other survey data on the use of out-of-hospital services of physicians in the West. The rate of persons X-rayed during dental visits in the North Central and South regions presents a reverse picture to that for medical X-ray visits in the same areas.

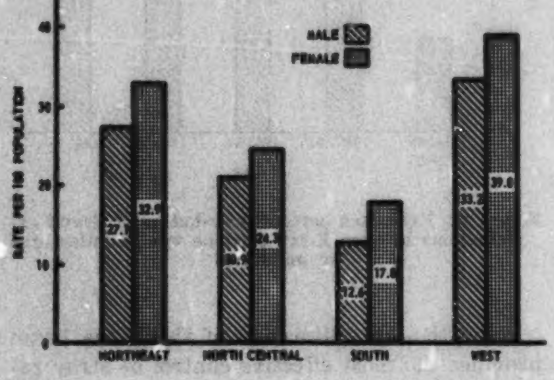

Figure 4. Estimated annual rate of dental X-ray visits (by age and sex)

Analysis of each type of procedure by age and sex (figure 5) reveals the rate for males X-rayed during medical visits to be higher than the rate for females. However, the annual rate for females X-rayed during dental visits is consistently higher than the rate for males over all age groups.

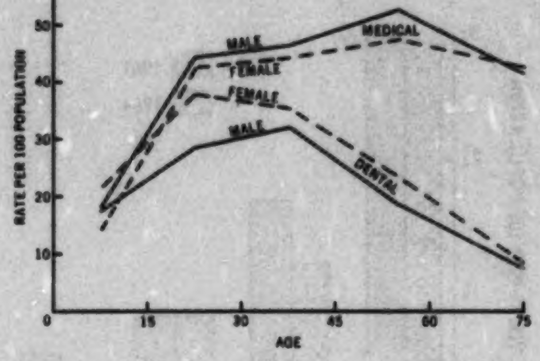

Figure 5. Estimated annual rates of medical and dental X-ray visits (by age and sex)

The estimated annual rate of persons X-rayed during medical visits was relatively constant over the various family income groups; whereas the annual rate of persons X-rayed during dental visits rises sharply as income increases (figure 6).

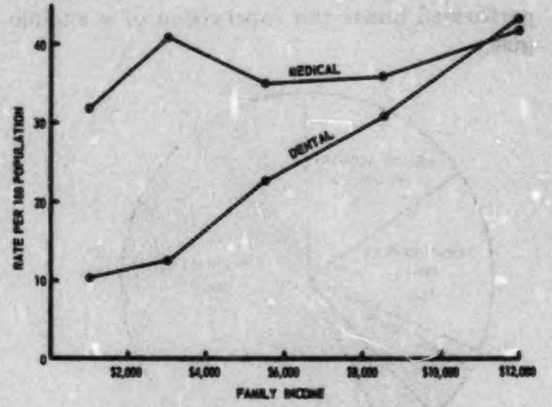

Figure 6. Estimated annual rate of medical and dental X-ray visits by family income

The observed increase in medical X-ray visits between 1961 and 1964 (figure 1) is reflected in the areas of the body examined (figure 7); the predominant increase being in visits involving abdominal X rays, most common among older persons.

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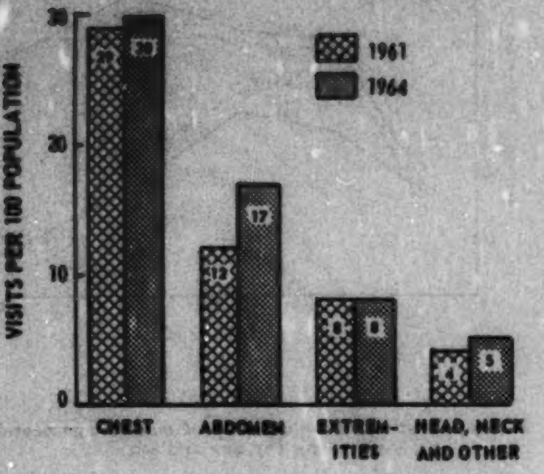

Figure 7. Estimated annual rate of medical X-ray visits by area of the body X rayed, 1961 and 1964

Fifty-eight percent of the medical X-ray procedures were performed in hospitals. Figure 8 also shows the percent distribution for other facilities where medical X-ray procedures were reported. In addition, the shaded area provides an estimate of the medical X-ray procedures performed under the supervision of a radiologist.

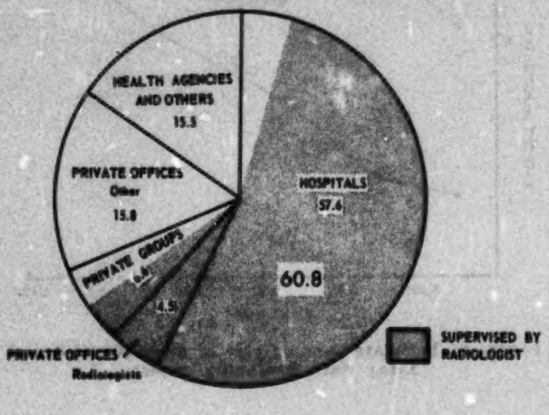

Figure 8. Estimated percent distribution of medical X-ray procedures by type of facility and supervision

Equipment proved to be of recent age (figures 9 and 10); almost 70 percent of the radiographic examinations reported in the study were performed on equipment manufactured or purchased in the last 10 years.

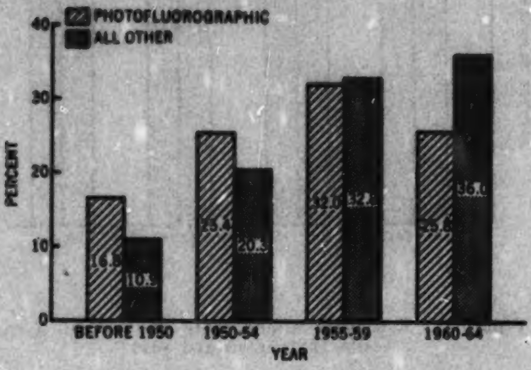

Figure 9. Estimated percent distribution of photofluorographic and radiographic examinations by year X-ray machine was manufactured or purchased

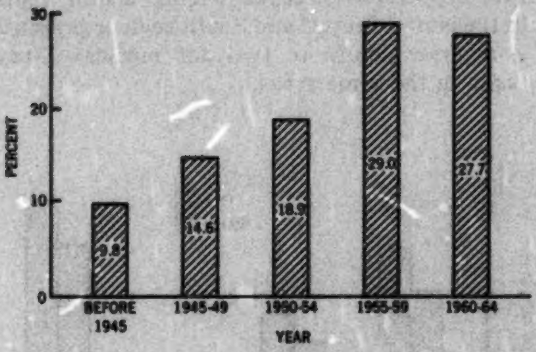

Figure 10. Estimated percent distribution of dental examinations by year X-ray machine was manufactured or purchased

Even though collimation of the X-ray beam provides the most effective control of stray radiation, more than one-half of all radiographic films had a beam size in excess of the reported film area plus a 25-percent allowance (table 1). More than 25 percent of these exposures were associated with beam areas that were two or more times larger than the film area plus the allowance. These excess beam sizes are an important finding of the study, since radiation not interrupted by a film or fluorescent screen is unnecessary radiation. Although misalignment can contribute to excess beam area, it did

Table 1. Percent distribution of radiographic film packs[a] by beam area as related to film area for reported film sizes

Film size	Number of films	Film area plus allowance[b] (percent of films)				
		Within 1X	1.0 to 1.9X	2.0 to 3.9X	4.0 to 5.9X	6X and over
All sizes	2,147	45.3	33.1	13.3	5.0	3.1
Photofluorographic	490	51.2	46.1	2.7	0.0	0.0
Radiographic	1,657	43.6	29.2	16.3	6.9	4.0
14 by 17	934	44.4	30.6	14.6	7.6	2.8
10 by 12	304	53.3	28.0	15.1	1.0	2.6
8 by 10	172	36.6	25.6	22.7	12.2	2.9
11 by 14	63	54.0	36.5	6.3	0.0	3.2
5 by 12	39	17.9	46.2	20.5	12.8	2.6
4 by 10	35	17.1	28.6	25.7	14.3	14.3
5 by 7	20	15.0	5.0	30.0	20.0	30.0
Others	90	36.7	18.9	24.4	5.6	14.4

[a] One hundred and eighty-three of the 2,330 film packs are excluded due to not calculable or not stated variables.
[b] Includes an additional 25 percent allowance for comparison with beam area.

not appear to be an important factor in contributing to beam areas that are larger than necessary. The International Commission on Radiological Protection has stated that use of light beam localizing devices would increase the accuracy with which a technician can direct the primary beam (*3*). In figure 11, no allowance of beam size has been added to film area.

Approximately 80 percent of the dental exposures recorded in the study were within the 3-inch maximum beam diameter at tip of pointer cone recommended by the National Committee on Radiation Protection and Measurements (*4*). Survey efforts sponsored by the U.S. Public Health Service indicate a continuing upward trend in the proportion of dental X-ray examinations within recommended beam diameters.

Of the 10.5 million fluoroscopic examinations, about 56 percent were gastrointestinal series and approximately 30 percent were barium enemas. Only 1 percent of the fluoroscopic examinations were performed at a source-to-tabletop distance of less than 12 inches. Thus, it appears that fluoroscopic machine design has been influenced by recommended standards.

Estimates of exposure in milliroentgens at the skin entrance were obtained for each film

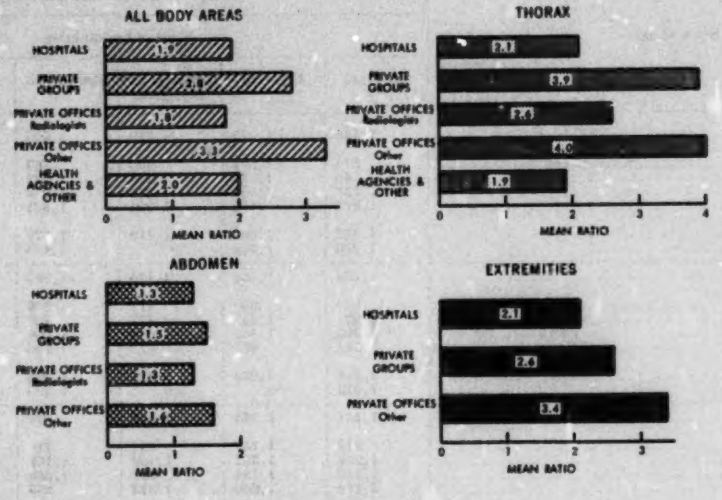

Figure 11. Estimated mean ratio of beam area to film area for radiographic films for selected body areas by type of facility

or exposure reported in the study. Mathematical models generated reference tables of mean milliroentgens per milliampere-second at 12 inches for varying kVp-filtration combinations necessary for assigning values, adjusted for body-part thickness (radiographic), to each recorded exposure. These estimates of exposure were produced to the nearest milliroentgen, although this precision should not be associated with these averages.

Estimated mean exposure values per film associated with dental examinations are given in table 2 and for radiographic examinations in table 3. For dental films, there is little difference in the average exposure per film by type of examination whereas, as one might expect, delineation of bony structures is associated with higher exposure values for radiographic films.

Estimates of exposure during fluoroscopic examinations were obtained by means of large-film dosimetry used during a subsequent similar procedure at the reported facility. Exposure per unit area resulted. Further development of this concept is being pursued through cooperative effort with the several universities engaged in X-ray dose model research.

Although the X-ray Exposure Study does not contain genetic or organ dose estimates for the U.S. population, work is currently underway to develop such data by age, sex, and type of X-ray procedure for presentation in the near future.

REFERENCES

(*1*) NATIONAL CENTER FOR HEALTH STATISTICS. Volume of X-ray visits, U.S., July 1960–June 1961. Series B–No. 38, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201 (1962).

(*2*) GITLIN, J. N., C. R. HAYMAN, R. G. PROCTOR, and P. L. RONEY. Field trial of a system to obtain data on population exposure to X-rays. Public Health Rep 79:186–192 (March 1964).

(*3*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Exposure of man to ionizing radiation arising from medical procedures. Physics Med Biol 2:107–156 (1957).

(*4*) U.S. DEPARTMENT OF COMMERCE. Medical X-ray protection up to three million volts. National Bureau of Standards Handbook 76. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401 (1961).

(*5*) U.S. BUREAU OF THE CENSUS. U.S. Census of Population: 1960, Final Report, PC(1)–1A. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20401.

Table 2. Estimated mean exposure per dental film by type of examination, sex, and age, 1964

Sex and age	Milliroentgens (at skin entrance)					
	Type of examination					
	All types	Bitewing	Bitewing and periapical	Full mouth	Periapical	All other
Both sexes	1,138	1,249	1,170	1,089	1,201	1,302
Under 15	878	1,087	809	763	863	1,239
15 to 29	1,149	1,326	1,417	839	1,375	(*)
30 to 44	1,185	1,161	1,272	1,076	1,219	(*)
45 and over	1,377	1,488	1,304	1,386	1,167	(*)
45 to 64	1,397	1,689	1,179	1,279	1,244	(*)
65 and over	1,346	1,249	(*)	1,433	878	(*)
Male	1,134	1,129	1,176	1,136	1,141	746
Under 15	833	988	471	839	683	(*)
15 to 29	1,021	1,337	1,277	723	1,282	(*)
30 to 44	1,305	1,191	1,344	1,026	1,384	(*)
45 and over	1,517	987	882	1,333	1,417	(*)
45 to 64	1,518	1,024	824	1,322	1,043	(*)
65 and over	1,513	(*)	(*)	1,369	2,473	(*)
Female	1,141	1,345	1,168	987	1,248	1,839
Under 15	912	1,127	784	714	1,017	(*)
15 to 29	1,382	1,301	1,439	1,109	1,330	(*)
30 to 44	1,110	1,134	986	1,066	1,296	(*)
45 and over	1,274	1,860	1,372	980	1,308	(*)
45 to 64	1,303	2,089	1,373	922	1,410	(*)
65 and over	1,089	1,494	(*)	1,452	735	(*)

* Outside confidence limits.

Table 3. Estimated mean exposure per film by type of radiographic[a] examination and type of facility, 1964

Type of examination	Milliroentgens (at skin entrance)					
	All	Hospitals	Private offices		Private groups	Health agencies and others
			Radiologists	Others		
Head and neck	379	377	341	377	396	(b)
Skull	[illegible]	[illegible]	(b)	(b)	(b)	(b)
Cervical spine	[illegible]	[illegible]	(b)	384	(b)	(b)
Head and neck, n.e.c.	379	[illegible]	(b)	(b)	(b)	(b)
Thorax						
[illegible]	[illegible]	[illegible]	(b)	(b)	(b)	c 531
[illegible]	[illegible]	[illegible]	84	64	48	82
[illegible]	[illegible]	[illegible]	(b)	(b)	(b)	(b)
[illegible]	1,[illegible]	1,371	(b)	(b)	(b)	(b)
[illegible]	1,047	1,088	(b)	(b)	(b)	(b)
Abdomen	780	748	686	1,338	780	1,4[illegible]
Upper abdomen:						
[illegible]	[illegible]	747	883	1,475	684	(b)
[illegible]	771	750	(b)	(b)	612	(b)
[illegible]	1,[illegible]	2,[illegible]	(b)	2,386	(b)	(b)
[illegible]	[illegible]	[illegible]	456	(b)	807	(b)
[illegible]	[illegible]	[illegible]	(b)	(b)	(b)	(b)
Lower abdomen:						
[illegible]	[illegible]	[illegible]	(b)	(b)	(b)	(b)
Abdomen, KUB, flat plate	[illegible]	[illegible]	779	1,108	780	(b)
[illegible]	[illegible]	[illegible]	858	(b)	(b)	(b)
[illegible]	[illegible]	[illegible]	(b)	(b)	(b)	(b)
[illegible]	[illegible]	[illegible]	(b)	807	644	(b)
[illegible]	2,[illegible]	2,[illegible]	(b)	(b)	(b)	(b)
Hip	1,[illegible]	1,375	(b)	(b)	(b)	(b)
Extremities	117	118	118	128	63	73
Upper extremities:						
Hand and/or wrist	127	[illegible]	(b)	[illegible]	49	(b)
Forearm or elbow	[illegible]	[illegible]	(b)	75	(b)	(b)
Lower extremities:						
Ankle	[illegible]	[illegible]	(b)	[illegible]	71	(b)
Foot and toes or heel	[illegible]	[illegible]	(b)	[illegible]	(b)	(b)
Knee	[illegible]	[illegible]	(b)	[illegible]	(b)	(b)
Hip and thigh	[illegible]	[illegible]	(b)	78	(b)	(b)
[illegible]	117	[illegible]	(b)	(b)	(b)	(b)

a Includes photofluorographic exposures.
b [illegible]
c Comprises mean exposure values of [illegible] for mobile units and [illegible] for stationary units.
Note: n.e.c., not elsewhere classified.

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SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to continuously monitor the intake of radionuclides from the diet. The most direct measure of radionuclide intake would be through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, one may assume the total daily dietary intake of selected radionuclides is equivalent to the intake represented by the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (May 1965).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1965).

23

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk.

In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–June 1966	March 1967

1. Pasteurized Milk Network
March 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN), was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent descrip-

Table 1. Analytical errors associated with determination of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error ᵃ (pCi/liter)	Concentration (pCi/liter)	Error ᵃ (percent of concentration)
Iodine-131	Less than 100	10	100 or greater	10
Barium-140	Less than 100	10	100 or greater	10
Cesium-137	Less than 100	10	100 or greater	10
Strontium-89	Less than 50	5	50 or greater	10
Strontium-90	Less than 20	2	20 or greater	10

ᵃ Two standard deviations.

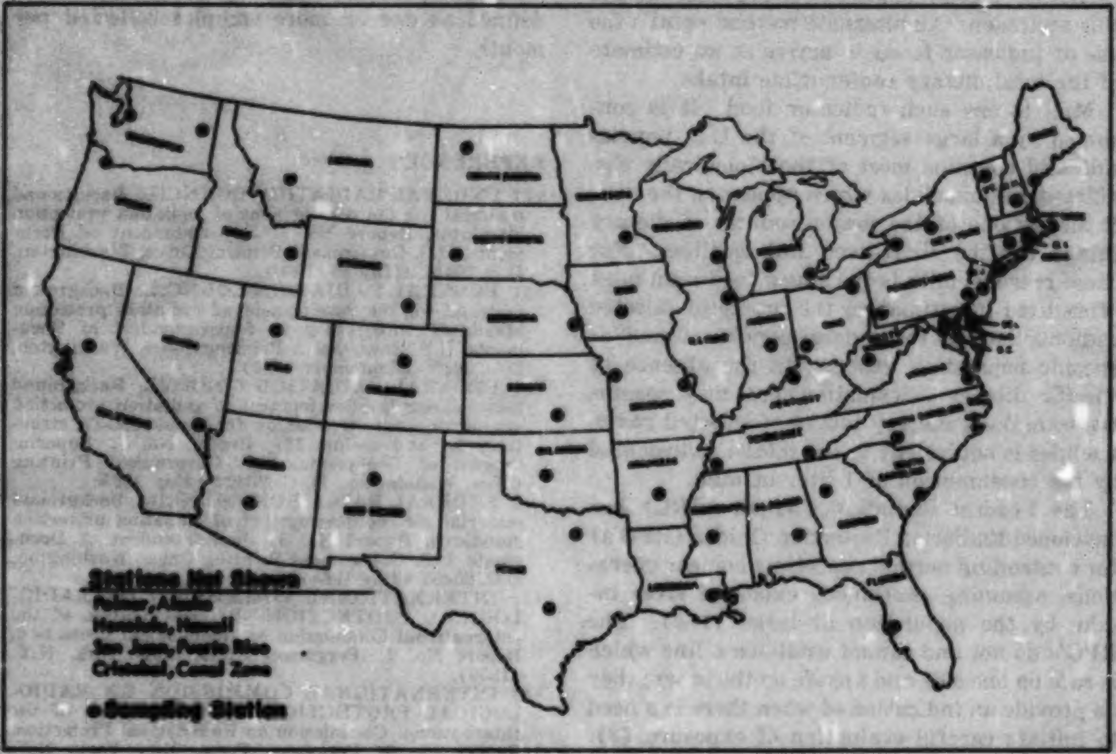

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for March 1967 and the first quarter 1967

Sampling location		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Iodine-131 (pCi/liter)		Cesium-137 (pCi/liter)		Barium-140 (pCi/liter)	
		March [a] 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967	March 1967	First quarter 1967
Ala:	Montgomery	< 5	<5	12	12	0	10	15	15	0	0
Alaska:	Palmer	< 5	<5	9	9	0	0	20	20	0	0
Ariz:	Phoenix	< 5	<5	3	3	0	0	< 5	< 5	0	0
Ark:	Little Rock	< 5	<5	22	23	0	0	25	20	0	0
Calif:	Sacramento	5	<5	3	3	0	0	< 5	< 5	0	0
	San Francisco	10	<5	4	4	0	0	5	< 5	0	0
C. Z:	Cristobal	< 5	<5	6	6	0	0	25	25	0	0
Colo:	Denver	< 5	<5	6	6	0	0	< 5	< 5	0	0
Conn:	Hartford			9	10	0	0	25	25	0	0
Del:	Wilmington			11	11	0	0	20	20	0	0
D. C:	Washington	< 5	<5	10	10	0	0	15	15	0	0
Fla:	Tampa	< 5	<5	9	9	0	0	65	70	0	0
Ga:	Atlanta	< 5	<5	16	17	0	10	25	25	0	0
Hawaii:	Honolulu	< 5	<5	9	8	0	0	20	15	10	0
Idaho:	Idaho Falls	< 5	<5	7	7	0	0	10	10	0	0
Ill:	Chicago	< 5	<5	10	8	0	0	25	20	0	0
Ind:	Indianapolis		<5	11	10	0	0	20	20	0	0
Iowa:	Des Moines	< 5	<5	9	9	0	0	10	10	0	0
Kans:	Wichita	< 5	<5	9	9	0	0	5	5	0	0
Ky:	Louisville	< 5	<5	14	15	0	0	15	15	0	0
La:	New Orleans	10	<5	21	25	0	0	25	25	0	0
Maine:	Portland		<5	12	12	0	0	45	45	0	0
Md:	Baltimore	< 5	<5	11	11	0	0	20	30	0	0
Mass:	Boston	< 5	<5	13	13	0	0	25	25	0	0
Mich:	Detroit			10	10	0	0	20	20	0	0
	Grand Rapids		<5	12	11	0	0	25	25	0	0
Minn:	Minneapolis	< 5	<5	14	14	0	0	15	15	0	0
Miss:	Jackson	10	<5	21	22	0	10	20	25	0	0
Mo:	Kansas City	< 5	<5	11	10	0	0	< 5	5	0	0
	St. Louis	< 5	<5	11	11	0	0	10	10	0	0
Mont:	Helena	< 5	<5	7	7	0	0	10	10	0	0
Nebr:	Omaha	< 5	<5	9	10	0	0	10	10	0	0
Nev:	Las Vegas	< 5	<5	3	3	0	0	< 5	< 5	0	0
N. H:	Manchester		<5	15	16	0	0	30	25	0	0
N. J:	Trenton		<5	10	10	0	0	25	25	0	0
N. Mex:	Albuquerque	< 5	<5	5	5	0	0	< 5	< 5	0	0
N. Y:	Buffalo		<5	9	9	0	0	20	20	0	0
	New York		<5	11	11	0	0	20	20	0	0
	Syracuse		<5	9	9	0	0	25	20	0	0
N. C:	Charlotte	< 5	<5	19	16	0	0	25	20	0	0
N. Dak:	Minot	< 5	<5	17	17	0	0	15	15	0	0
Ohio:	Cincinnati		<5	11	11	0	0	20	20	0	0
	Cleveland		<5	11	12	0	0	20	20	0	0
Okla:	Oklahoma City	< 5	<5	10	11	0	0	10	10	0	0
Oreg:	Portland	< 5	5	8	8	0	0	5	10	0	0
Penn:	Philadelphia		<5	11	11	0	0	20	20	0	0
	Pittsburgh			13	13	0	0	25	25	0	0
P. R:	San Juan	< 5	<5	6	6	0	0	15	15	0	0
R. I:	Providence		<5	11	11	0	0	20	20	0	0
S. C:	Charleston	< 5	<5	17	19	0	20	20	20	0	0
S. Dak:	Rapid City	< 5	<5	10	11	0	0	10	15	0	0
Tenn:	Chattanooga	< 5	<5	16	17	0	0	20	20	0	0
	Memphis	< 5	<5	12	13	0	0	10	10	0	0
Tex:	Austin	< 5	<5	3	4	0	20	5	15	0	0
	Dallas	< 5	<5	9	9	0	10	10	10	0	0
Utah:	Salt Lake City	< 5	<5	6	7	0	0	10	10	0	0
Vt:	Burlington		<5	11	11	0	0	25	25	0	0
Va:	Norfolk	< 5	<5	12	12	0	0	15	15	0	0
Wash:	Seattle	< 5	<5	14	11	0	0	25	25	0	0
	Spokane	< 5	<5	11	11	0	0	20	20	0	0
W. Va:	Charleston	< 5	<5	11	15	0	0	15	15	0	0
Wis:	Milwaukee			8	8	0	0	20	20	0	0
Wyo:	Laramie	< 5	<5	4	7	0	0	< 5	10	0	0
Network average		< 5	<5	10.7	10.8	0	0	20	20	0	0

[a] Blank indicates no strontium-89 determinations were made on samples from station during month.

tion of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

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Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The results for March 1967 and first quarter of 1967 are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable values; however, for iodine-131 and barium-140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium-90 and cesium-137 are presented in tables 3 and 4 for March 1966 and October 1966 through March 1967. The average strontium-90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution of monthly average strontium-90 concentrations in milk at PMN stations, March 1966, October–December 1966, and January–March 1967

Strontium-90 (pCi/liter)	Number of stations						
	1966				1967		
	Mar	Oct	Nov	Dec	Jan	Feb	Mar
Under 10	9	18	19	23	24	21	25
10–19	44	39	40	35	36	38	35
20–29	7	6	4	5	3	4	2
30–39	3	0	0	0	0	0	1

Table 4. Frequency distribution of monthly average cesium-137 concentration in milk at PMN stations, March 1966, October–December 1966, and January–March 1967

Cesium-137 (pCi/liter)	Number of stations						
	1966				1967		
	Mar	Oct	Nov	Dec	Jan	Feb	Mar
Under 50	56	62	61	62	62	62	62
50–99	6	0	2	1	1	1	1
100–149	1	1	0	0	0	0	0

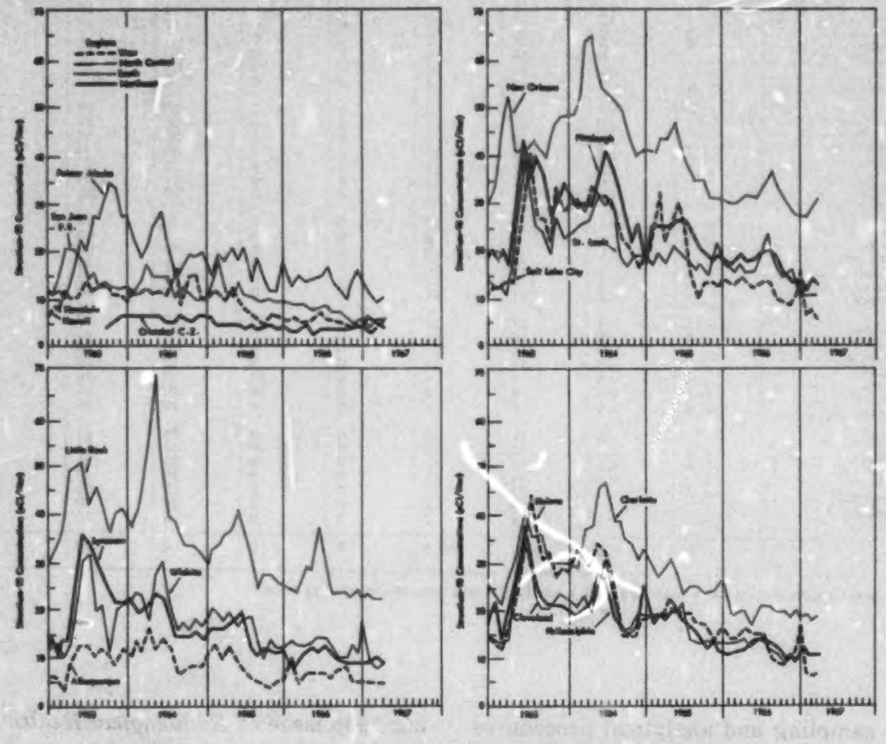

Figure 2. Strontium-90 concentrations in pasteurized milk, 1961–March 1967

2. Canadian Milk Network
March 1967[1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (2).

The March 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

Table 5. Stable elements and radionuclides in Canadian whole milk, March 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.17	1.4	12.7	37
Edmonton	1.14	1.5	11.0	38
Ft. William	1.13	1.5	17.2	44
Fredericton	1.13	1.4	16.1	18
Halifax	1.17	1.6	16.6	40
Montreal	1.11	1.5	10.6	29
Ottawa	1.17	1.5	10.8	25
Quebec	1.10	1.5	14.8	53
Regina	1.16	1.5	10.0	26
St. John's, Nfld	1.11	1.6	20.2	56
Saskatoon	1.16	1.5	12.4	32
Sault Ste. Marie	1.12	1.6	15.5	40
Toronto	1.15	1.4	7.0	19
Vancouver	1.20	1.6	17.2	70
Windsor	1.18	1.5	6.2	21
Winnipeg	1.18	1.6	10.8	36
Average	1.15	1.5	13.1	38

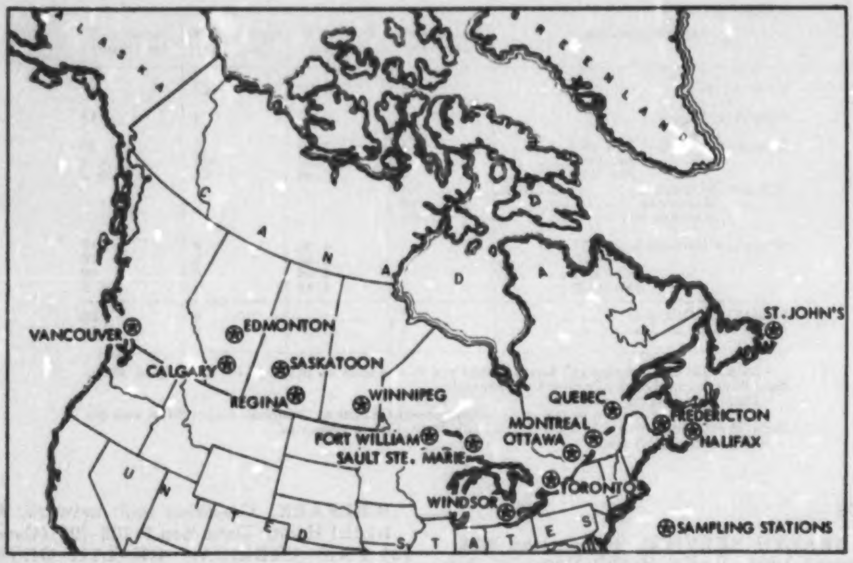

Figure 3. Canadian milk sampling stations

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[1] Prepared from April 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Milk Sampling Program March 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a numer of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 6 presents stable calcium and potassium, strontium-90, and cesium-137 monthly average concentrations for March 1967.

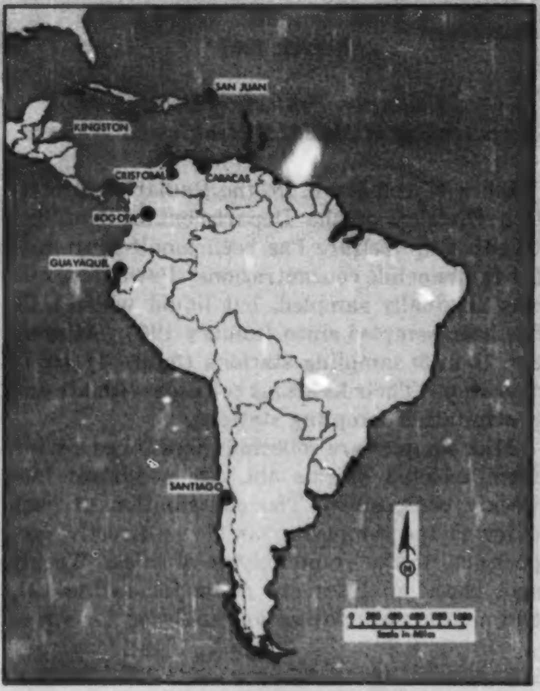

Figure 4. Pan American Milk Sampling Program stations

Table 6. Stable element and radionuclide concentration in PAHO milk[a] March 1967

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile: Santiago	4	1.53	<1	11
Colombia: Bogota	1	1.38	1	15
Ecuador: Guayaquil, Mar 1967	4	1.43	<1	10
Jan 1967	4	1.35	<1	< 5
Feb 1967	4	1.44	<1	< 5
Jamaica: Kingston	NS			
Mandeville	NS			
Montego Bay	NS			
Venezuela: Caracas, Mar 1967	1	1.41	4	10
Dec 1966	1	1.35	3	10
Jan 1967	1	1.34	5	10
Feb 1967	1	1.46	2	< 5
Canal Zone: Cristobal[c]	4	----------	5	35
Puerto Rico: San Juan[c]	4	----------	6	15

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples. Strontium-89 was less than 5 pCi/liter for all samples.

[b] Data not previously presented.

[c] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network, are presented.

NS, no sample collected.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7: 698–701 (December 1966).

(*2*) RADIATION PROTECTION DIVISION, DEPARTMENT OF NATIONAL HEALTH AND WELFARE. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have established comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

State milk network	Period reported	Last presented
California	October–December 1966	June 1967
Connecticut	October–December 1966	May 1967
Indiana	October–December 1966	May 1967
Michigan	October–December 1966	May 1967
Minnesota	October–December 1966	May 1967
Oregon	October–December 1966	June 1967
New York	October–December 1966	May 1967
Pennsylvania	October–December 1966	May 1967
Washington	October–December 1966	June 1967

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1. Colorado Milk Network
January–March 1967

Occupational and Radiological Health Division
Colorado State Department of Public Health

The Radiological Health Division of the Colorado State Department of Public Health initiated radiological analysis of milk in January 1962. Initially, the Denver City and County Health Department collected a weekly composite milk sample from the major producers in the Denver area for the State, as it had for the Public Health Service since March 1960.

In August 1962, the State expanded its program to include the routine sampling of raw milk from the four major milk producing areas supplying the State: northeast, southeast, western Colorado, and eastern Utah. Areas of the State presently sampled are western, south central, northeastern, and eastern Colorado (including northwestern Kansas). Colorado milkshed areas are shown in figure 1.

Recent analyses have been on samples of raw milk coming into the State Health Department specifically for gamma-ray analysis. January sampling was intensified in response to the mainland Chinese atmospheric nuclear test of December 1966.

Analyses are performed for iodine–131, barium–140, cesium–137, and potassium by gamma-ray spectroscopy. The measurement system previously reported upon (*1*) has been adapted to utilize a 4- by 5-inch NaI crystal shielded by a lead-lined bank safe.

Minimum detectable amounts at the 2σ counting error equivalent are iodine–131 (10 pCi/liter); barium-lanthanum–140 (15 pCi/liter); cesium–137 (10 pCi/liter); and potassium (0.2 g/liter).

Table 1 gives results of the measurements of radionuclides in milk collected from January through March 1967. Barium-lanthanum–140 was not detected during this period. Analyses for the last half of 1966 were not reported due to a temporary curtailment of the program during that period.

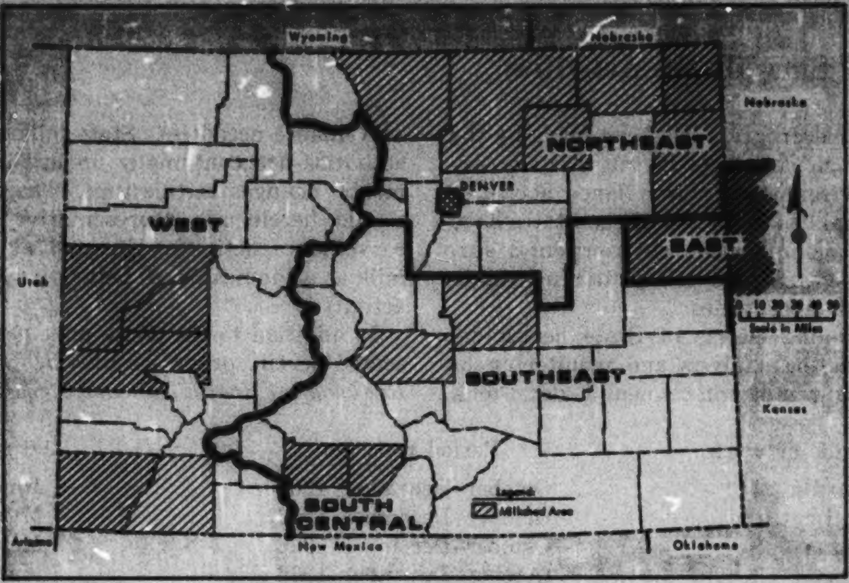
Wyoming
Nebraska
Nebraska
NORTHEAST
DENVER
WEST
EAST
Utah
0 10 20 30 40 50
Scale in Miles
SOUTHEAST
Kansas
Legend
▨ Milkshed Area
SOUTH CENTRAL
Arizona
New Mexico
Oklahoma

Figure 1. Colorado milk sampling areas

Table 1. Radionuclides in Colorado raw milk, January–March 1967

Date of sampling 1967	Area sampled [a]	Number of samples analysed	Number of samples containing detectable radionuclides [b]	Concentration of detectable radionuclides (pCi/liter)	
				Iodine-131	Cesium-137
January 3	W	2			
4	W	4	1		10
4	NE	7			
4	E	1			
5	W	1			
9	W	1			
10	W	1			
12	E	1			
12	NE	11			
February 27	NE	2	2		13, 15
27	E	1			
28	NE	2	1		14
28	W	2	1	10	12
March 20	E	1			
21	NE	1			
22	NE	1			
23	NE	1			
27	W	1			

[a] W—western Colorado
NE—northeastern Colorado
E—eastern Colorado (including northwestern Kansas)

[b] Minimum detectable activity is taken as equal to or greater than the 2σ counting error equivalent and for the two radionuclides given is 10 pCi/liter.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
October–December 1964 and summaries 1962–1964	April 1965
May 1965–June 1966	October 1966

2. Oklahoma Milk Network
January–March 1967

Oklahoma State Department of Health[1]

On March 15, 1965, the Radiological Health Section of the Oklahoma State Department of Health initiated a program of analysis for iodine-131 in the milk produced in the State of Oklahoma.

The location of the sampling stations and the extent of their associated milksheds are shown in figure 2. Of the 10 milksheds in the State of Oklahoma, 5 were chosen as sampling stations (Oklahoma City, Enid, Tulsa, Lawton, and Ardmore) on the basis of their size and location. A major criterion in the selection of a milkshed for sampling was the degree of overlap with other milksheds being sampled. This overlap assists in locating small areas of production where the iodine-131 concentrations might be abnormally high.

The sampling stations are located in the laboratory of a major milk processing plant in each milkshed. While the milkshed for a particular processing plant may not coincide exactly with that shown in figure 2 the coincidence is satisfactory for surveillance purposes.

At the present time, samples are collected on Monday morning, and the analyses are completed by Wednesday afternoon. However, if iodine-131 levels detected are such that diversion of the milk or other precautionary methods need to be taken, the analytical method and equipment can be employed to sample each truck arriving at the processing plant. Under these conditions, only about 4 hours would be needed to complete the analysis. This greatly reduced lag time for analysis would permit rapid decisions on the fate of each truckload of raw milk.

Analytical method

The method of analysis is similar to that recently published by the U.S. Public Health Service (2) but was developed independently by the Oklahoma State Health Department's Radiological Health Laboratory.

Results and discussion

Table 2 gives the concentrations of iodine-131 found in Oklahoma milk samples collected from January through March 1967. Cesium-137 concentrations are presented in table 3.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	January 1967
October–December 1966	April 1967

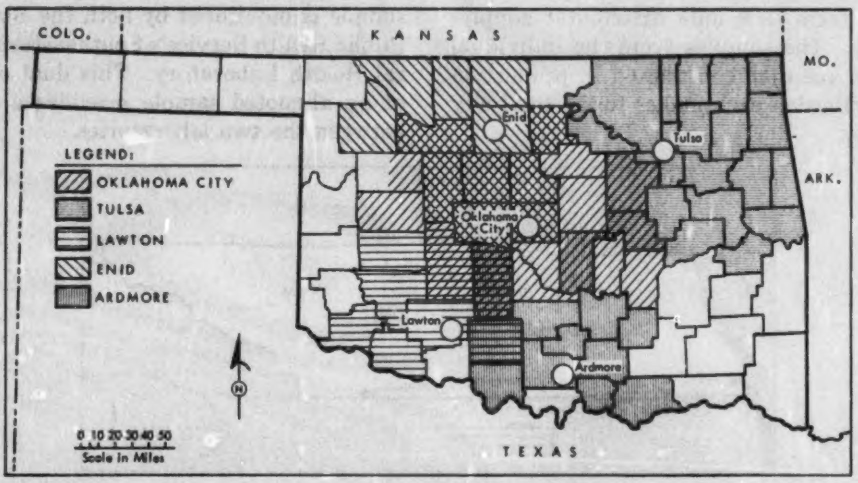

Figure 2. Oklahoma milkshed sampling areas

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[1] Acknowledgement is accorded to the staff of the Radiological Health Section under the direction of Mr. Dale McHard, head, and Mr. Robert Craig, assistant engineer.

Table 2. Concentration of iodine-131 in Oklahoma pasteurized milk, January–March 1967

Sampling date 1967	Sampling location Radionuclide concentrations (pCi/liter)				
	Oklahoma City	Enid	Tulsa	Lawton	Ardmore
January 2	IF	IF	IF	IF	IF
9	24	24	2	2	22
16	10	NS	32	NS	NS
23	4	NS	9	ND	ND
30	ND	6	4	ND	4
February 10	ND	ND	12	19	ND
17	ND	ND	ND	ND	ND
24	ND	ND	9	ND	ND
March 3	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND
17	ND	ND	13	11	19
24	ND	ND	ND	ND	ND
31	ND	ND	ND	ND	ND

IF, instrument failure.
NS, no sample collected.
ND, nondetectable, less than 3 pCi/liter.

Table 3. Concentration of cesium-137 in Oklahoma pasteurized milk, January–March 1967

Sampling date 1967	Sampling location Radionuclide concentration (pCi/liter)				
	Oklahoma City	Enid	Tulsa	Lawton	Ardmore
January 2	IF	IF	IF	IF	IF
9	ND	89	ND	ND	14
16	ND	NS	17	NS	NS
23	19	NS	ND	ND	ND
30	ND	ND	ND	13	ND
February 10	ND	ND	15	26	ND
17	ND	73	24	ND	9
24	ND	ND	39	ND	ND
March 3	ND	ND	ND	18	ND
10	17	ND	ND	ND	ND
17	10	25	19	ND	ND
24	11	13	ND	ND	ND
31	13	19	17	ND	ND

IF, instrument failure.
ND, not detectable—less than 10 pCi/liter.
NS, no sample collected.

3. Tennessee Milk Network
January–March 1967

Division of Preventable Diseases
Department of Public Health
State of Tennessee

The Tennessee Department of Public Health began sampling pasteurized milk for radionuclide analysis in July of 1965. Currently the Department is collecting semimonthly milk samples from three cities (figure 3). In order to obtain a representative sample the milk consumed in the areas monitored, a sample of milk is collected from each milk distributor supplying the city. The samples from the individual distributors are then composited in proportion to the contribution each makes to the total city milk supply.

Analytical procedures

The semimonthly milk samples from each city sampled are analyzed by gamma-ray scintillation spectrometry for potassium-40, iodine-131, cesium-137, and barium-140, using a 3½-liter sample. After gamma-ray analysis, the samples are stored for 2 weeks to allow ingrowth of daughter activity, after which strontium-89, strontium-90, and barium-140 concentrations are determined radiochemically using ion exchange procedures. Chemical analyses are also made for stable calcium and potassium.

It can be noted that the Chattanooga milk sample is monitored by both the State and the Public Health Service's Southeastern Radiological Health Laboratory. This dual examination of an aliquoted sample provides a cross-check between the two laboratories.

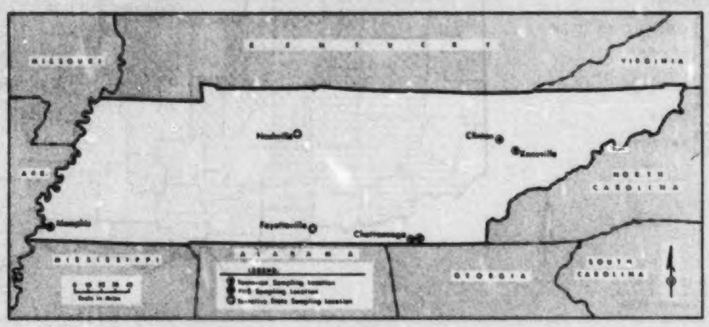

Figure 3. Tennessee pasteurized milk sampling stations

Results

The monthly average stable element and radionuclide concentrations in Tennessee pasteurized milk are presented in table 4 for the period of January through March 1967.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1965–June 1966	April 1967

Table 4. Radionuclides in Tennessee pasteurized milk, January–March 1967

Location	Month 1967	Concentration (g/liter)	Radionuclide concentration (pCi/liter)				
		Potassium	Strontium-89	Strontium-90	Iodine-131	Cesium-137	Barium-140
Chattanooga	Jan	1.6	<5	19	24	26	<5
	Feb	1.4	<5	21	< 5	19	<5
	Mar	1.4	<5	24	10	21	<5
Clinton	Jan	1.4	<5	17	51	35	7
	Feb	1.3	<5	24	15	23	<5
	Mar	1.3	<5	33	12	26	<5
Knoxville	Jan	1.6	<5	16	9	22	7
	Feb	1.5	<5	15	10	15	<5
	Mar	1.4	<5	18	14	19	<5

4. Texas Milk Network
January–March 1967

Texas State Department of Health [3]

The Texas State Department of Health initiated a statewide milk sampling network for radionuclide content in April 1964. At present, monthly samples of raw milk are collected from each of seven "active" sampling points. In addition, six "standby" stations have been supplied sample containers and shipping instructions and can be activated immediately if needed. The "active" and "standby" station locations, shown in figure 4 were chosen to give maximum geographical and population coverage.

Samples are routinely analyzed for strontium–89 and strontium–90 by a chemical separation technique employing ion exchange columns (*4*). Prepared samples are counted for 100 minutes in a low-background beta-particle counter.

Potassium–40, iodine–131, barium–140 and cesium–137 concentrations are determined by gamma-ray scintillation spectrometry. The procedure employs a 4- by 4-inch sodium iodide crystal and a 400-channel analyzer. Samples are counted for 100 minutes in a 3½ liter Marinelli beaker. The matrix method of calculation is used and detection limits at the 95-percent confidence level are 10 pCi/liter.

Results

Potassium–40, strontium–90, iodine–131, and cesium–137 results by station and month for January through March 1967 are presented in table 5. During this time, the strontium–89 and barium–140 concentrations were below their limits of detectability (5 and 10 pCi/liter, respectively). A summary of radionuclide concentrations in Texas milk is presented graphically in figure 5 for the period from April 1964 through March 1967.

Comparison of the observed radionuclide concentrations with the Federal Radiation Council guides for peacetime operations indicates that at no time during the period of surveillance did the radionuclide concentrations in Texas milk approach levels suggesting any remedial action (*5*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	January 1967
October–December 1966 and annual summary 1966	April 1967

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[3] Acknowledgement is accorded to the staff of the Radiation Control Program, Division of Occupational Health and Radiation Control, under the direction of Mr. Martin C. Wukasch, chief engineer.

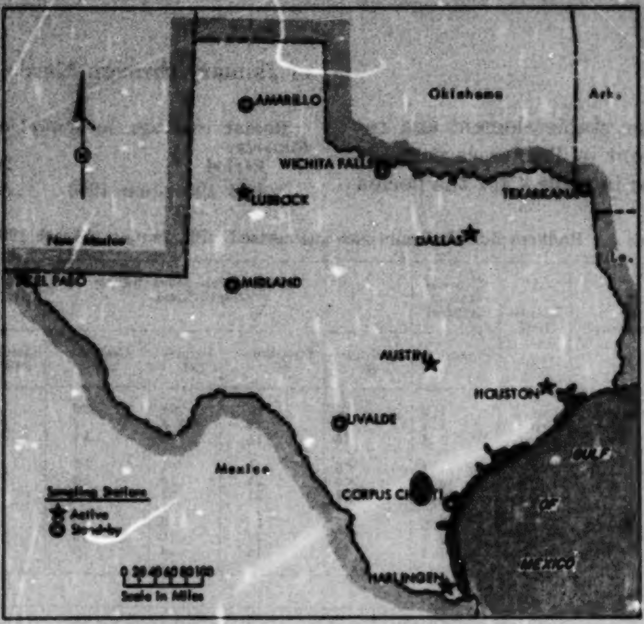
Oklahoma
Ark.
AMARILLO
WICHITA FALLS
LUBBOCK
TEXARKANA
DALLAS
New Mexico
La.
EL PASO
MIDLAND
AUSTIN
HOUSTON
UVALDE
Mexico
GULF
OF
MEXICO
CORPUS CHRISTI
HARLINGEN
Sampling Station
Active
Stand-by
0 20 40 60 80 100
Scale in Miles

Figure 4. Texas milk sampling stations

Table 5. Radionuclide concentrations in Texas milk network, January–March 1967

Sampling location	Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Iodine-131 (pCi/liter)			Cesium-137 (pCi/liter)		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Austin	1,300	1,280	1,250	6	5	4	40	ND	ND	10	10	5
Fort Worth	1,260	1,310	1,260	6	7	6	ND	ND	ND	10	15	10
El Paso	1,230	1,310	1,410	4	4	2	ND	ND	ND	10	10	10
Harlington	1,320	1,360	1,300	3	3	3	20	ND	ND	10	5	5
Houston	1,240	1,330	1,320	14	12	8	10	ND	ND	15	15	15
Lubbock	1,350	1,250	1,320	8	5	5	ND	ND	ND	10	10	5
San Antonio	1,270	1,420	1,300	5	7	4	ND	ND	ND	10	10	5
Average	1,280	1,320	1,310	7	6	5	12	ND	ND	11	11	8

ND, non-detectable.

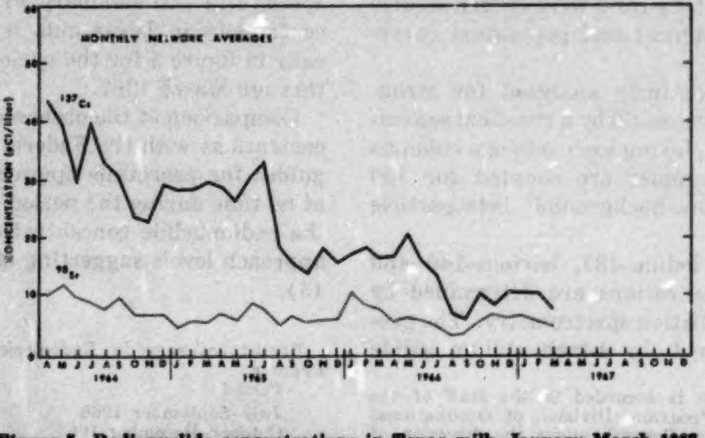

Figure 5. Radionuclide concentrations in Texas milk, January–March 1967

REFERENCES

(1) COLORADO STATE DEPARTMENT OF PUBLIC HEALTH, OCCUPATIONAL AND RADIOLOGICAL HEALTH DIVISION. Colorado milk network, October–December 1964 and summary 1962–1964. Radiol Health Data 6:202–204 (April 1965).

(2) PORTER, C. R., and M. W. CARTER. Field method for rapid collection of iodine-131 from milk. Public Health Rep 80:453–455 (May 1965).

(3) OKLAHOMA STATE DEPARTMENT OF HEALTH. Oklahoma milk network, March–July 1965. Radiol Health Data 6:540–541 (October 1965).

(4) PORTER, C., and B. KAHN. Improved determination of strontium-90 in milk by ion exchange method. Anal Chem 36:676–678 (March 1964).

(5) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Food and Diet Surveillance Activities

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet	May–August 1966	May 1967
Connecticut Standard Diet	July–December 1966	May 1967
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	May–June 1966	June 1967
United Kingdom Diet	Annual summary 1965	December 1966

1. Radionuclides in Institutional Diet Samples October–December 1966

National Center for Radiological Health
Public Health Service

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the National Center for Radiological Health with the assistance of the National Center for Urban and Industrial Health (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of July 1965, 21 institutions, distributed geographically as shown in figure 1, were being sampled. Previous results showed that the daily intake of teenage girls and children from 9 to 12 years of age were comparable while teenage boys consumed 20 percent more food per day (*1,2*). Consequently, estimates for teenage boys and/or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample supplied monthly by each institution represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drink-

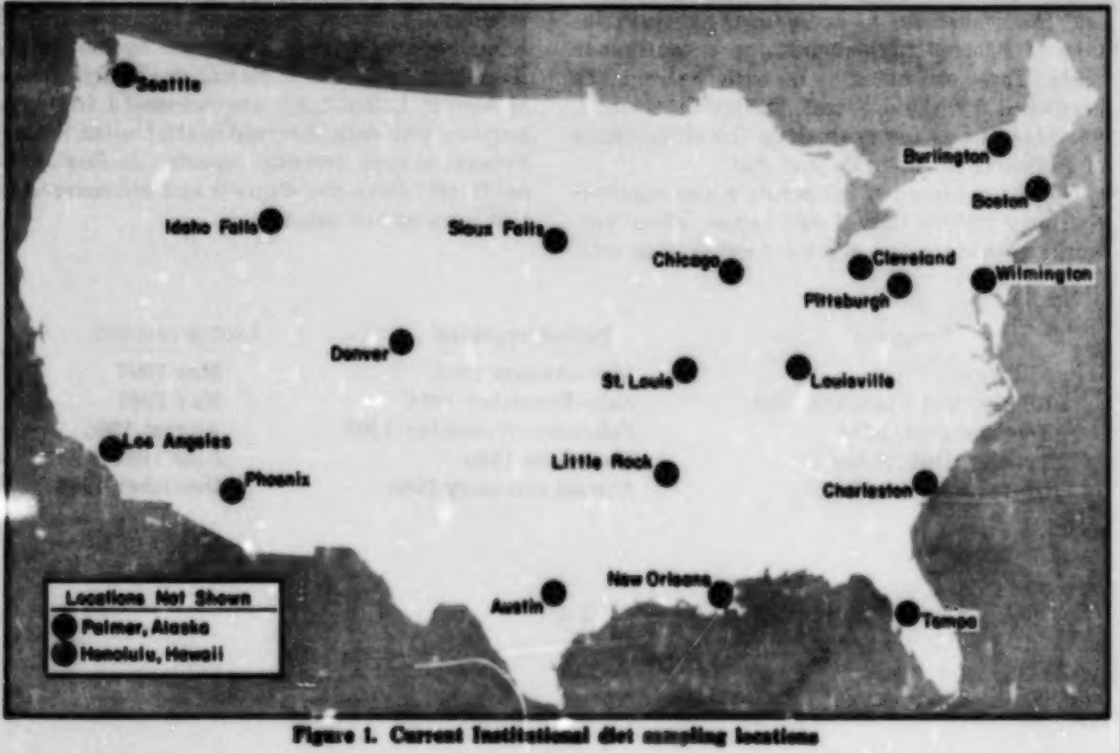
Seattle
Burlington
Boston
Idaho Falls
Sioux Falls
Chicago
Cleveland
Wilmington
Pittsburgh
Denver
St. Louis
Louisville
Los Angeles
Phoenix
Little Rock
Charleston
New Orleans
Austin
Tampa
Locations Not Shown
Palmer, Alaska
Honolulu, Hawaii

Figure 1. Current institutional diet sampling locations

ing water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period, and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev.; the Southeastern Radiological Health Laboratory, Montgomery, Ala.; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and

Table 1. Stable element and radionuclide concentration in institutional total diets of children, October–December 1966

Location of institution	Month 1966	Stable element (g/kg of diet)		Radionuclide concentration (pCi/kg of diet)			
		Calcium	Potassium	^{89}Sr	^{90}Sr	^{137}Cs	^{226}Ra
Alaska: Palmer	Oct	0.8	1.2	< 5	11	42	0.9
	Nov	1.0	1.3	< 5	71	66	1.3
	Dec	.8	1.3	< 5	9	60	.3
Ariz: Phoenix	Oct	.8	1.0	< 5	9	15	1.5
	Nov	.8	1.1	< 5	7	15	1.3
	Dec	.8	1.3	< 5	7	10	.4
Ark: Little Rock	Oct	.9	[illegible]	NA	15	15	1.1
	Nov	.8	[illegible]	NA	11	15	NA
	Dec	.9	[illegible]	NA	15	15	.9
Calif: Los Angeles	Oct	[illegible]	[illegible]	< 5	6	25	2.2
	Nov	1.[illegible]	[illegible]	< 5	6	20	.8
	Dec	[illegible]	[illegible]	< 5	6	20	1.0
Colo: Denver	Oct	.8	1.4	< 5	7	15	1.3
	Nov	.7	1.2	< 5	9	8	1.1
	Dec	.9	1.4	< 5	6	10	1.1
Del: Wilmington	Oct	.8	1.5	< 5	16	25	.7
	Nov	.9	1.6	< 5	11	25	.8
	Dec	.7	1.6	< 5	8	25	.9
Fla: Tampa	Oct	.6	1.6	NA	10	100	[illegible]
	Nov	.6	1.6	NA	10	45	NA
	Dec	.6	1.6	NA	10	30	1.7
Hawaii: Honolulu	Oct	.4	1.1	< 5	4	20	.8
	Nov	.4	1.1	< 5	6	25	.8
	Dec	.5	1.2	< 5	4	25	.9
Idaho: Idaho Falls	Oct	1.0	1.6	< 5	12	20	.6
	Nov	.9	1.7	< 5	9	20	.7
	Dec	.9	1.7	< 5	12	20	.8
Ill: Chicago	Oct	.8	1.6	< 5	7	25	.8
	Nov	.7	1.7	< 5	7	25	.5
	Dec	.7	1.6	< 5	8	25	.9
Ky: Louisville	Oct	.6	1.4	NA	8	15	1.5
	Nov	.8	1.6	NA	11	20	NA
	Dec	.8	1.6	NA	10	15	1.8
La: New Orleans	Oct	.7	1.7	< 5	17	25	.8
	Nov	.6	1.7	< 5	17	20	NA
	Dec	.4	1.5	10	9	10	1.0
Mass: Boston	Oct	.7	1.6	< 5	11	25	.7
	Nov	.8	1.9	< 5	10	25	.6
	Dec	.8	1.8	< 5	11	30	.7
Mo: St. Louis	Oct	NS	NS	NS	NS	NS	NS
	Nov	.9	1.7	< 5	11	20	.8
	Dec	.8	1.6	< 5	8	10	.8
Ohio: Cleveland	Oct	.7	1.7	< 5	7	20	.6
	Nov	.8	1.9	< 5	7	25	.6
	Dec	.6	1.8	< 5	8	15	.7
Pa: Pittsburgh	Oct	.5	1.4	< 5	9	25	.9
	Nov	.6	1.4	< 5	10	20	.6
	Dec	.6	1.3	< 5	9	20	.8
S. C: Charleston	Oct	.5	1.1	< 5	16	25	1.7
	Nov	.6	1.4	< 5	11	30	NA
	Dec	.7	1.4	< 5	14	25	1.2
S. Dak: Sioux Falls	Oct	NS	NS	NS	NS	NS	NS
	Nov *	.4	1.4	< 5	6	20	.7
	Dec	.6	1.6	< 5	5	15	.7
Tex: Austin	Oct	.6	1.4	NA	7	15	1.1
	Nov	.4	1.1	NA	7	8	NA
	Dec	.5	1.2	NA	7	15	1.0
Vt: Burlington	Oct	.6	1.6	< 5	12	20	.9
	Nov	.6	2.0	< 5	12	40	.5
	Dec	.8	1.6	< 5	10	30	1.0
Wash: Seattle	Oct	1.2	1.2	< 5	18	5	1.0
	Nov	1.2	1.4	< 5	16	65	1.1
	Dec	.6	1.6	< 5	7	60	.4
Institutional average	Oct	0.7	1.5	< 5	10	25	1.1
	Nov	0.7	1.5	< 5	12	25	0.9
	Dec	0.7	1.5	< 5	9	20	0.8

* Since milk component of the diet was not sent to the laboratory, concentrations are based only on solid and other liquid components of the diet.

NA, no analysis.

NS, no sample.

Note: Since iodine-131 and barium-140 concentrations were not detectable at most stations during the fourth quarter 1966, no provision was made for these nuclides in the table. The few exceptions are as follows:

October 1966, 10 pCi/kg of iodine-131 was reported for Louisville, Ky.

December 1966, 10 pCi/kg of iodine-131 was reported for Phoenix, Ariz.; Palmer, Alaska; Tampa, Fla.; and New Orleans, La.

December 1966, barium-140 was reported in the following institutions: Palmer, Alaska, 15 pCi/kg; Long Beach, Calif., 16 pCi/kg; and Austin, Tex., 12 pCi/kg.

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Table 2. Intake of stable elements and radionuclides in institutional total diet for children (9 to 12 years of age), October–December 1966

Location of institution		Month 1966	Total weight (kg/day)	Stable element intake (g/day)		Radionuclide intake (pCi/day)			
				Calcium	Potassium	^{89}Sr	^{90}Sr	^{137}Cs	^{226}Ra
Alaska:	Palmer	Oct	1.78	0.9	2.1	5	30	80	1.6
		Nov	1.14	1.1	1.8	5	51	75	2.0
		Dec	1.80	1.0	2.5	5	15	60	0.4
Ariz:	Phoenix	Oct	2.22	1.3	2.2	5	30	35	2.3
		Nov	2.08	1.0	2.2	5	15	30	2.6
		Dec	1.61	1.0	2.4	5	8	15	.6
Ark:	Little Rock	Oct	1.13	.7	2.0	NA	15	15	1.2
		Nov	1.14	.6	1.7	NA	13	15	NA
		Dec	1.15	.6	1.7	NA	17	10	1.0
Calif:	Los Angeles	Oct	1.80	1.5	3.4	5	11	65	4.2
		Nov	2.10	2.3	3.0	5	13	65	1.9
		Dec	2.01	1.2	2.4	5	12	10	2.0
Colo:	Denver	Oct	2.18	1.7	3.1	5	15	25	2.8
		Nov [a]	1.80	1.3	2.2	5	16	10	2.0
		Dec	2.08	1.7	2.9	5	12	20	2.3
Del:	Wilmington	Oct	2.10	1.3	3.8	5	21	55	1.8
		Nov	1.91	1.5	3.4	5	21	50	1.8
		Dec	1.86	1.4	2.9	5	16	50	1.3
Fla:	Tampa	Oct	2.25	1.4	3.4	NA	22	255	2.7
		Nov [b]	2.12	1.1	3.4	NA	21	95	NA
		Dec	2.05	1.2	3.7	NA	20	100	3.5
Hawaii:	Honolulu	Oct [a]	1.90	.5	2.2	5	8	40	1.2
		Nov	1.90	.5	2.1	5	12	50	1.2
		Dec	2.04	1.0	1.2	5	8	70	1.8
Idaho:	Idaho Falls	Oct [a]	1.86	2.0	3.5	5	24	80	1.2
		Nov [a]	2.28	2.0	3.8	5	20	65	1.6
		Dec [a]	2.21	2.0	3.8	5	29	45	1.1
Ill:	Chicago	Oct	1.51	.9	2.1	5	11	40	1.2
		Nov [a]	1.77	1.2	3.0	5	12	45	1.4
		Dec	1.17	.8	1.9	5	9	30	1.1
Ky:	Louisville	Oct [a]	1.44	.9	2.0	NA	12	30	2.2
		Nov [a]	1.82	1.5	2.9	NA	20	35	NA
		Dec [a]	1.98	1.6	3.1	NA	20	30	3.5
La:	New Orleans	Oct	1.80	1.1	2.6	5	26	40	1.2
		Nov [b]	1.41	.8	2.4	5	24	30	NA
		Dec [b]	1.36	.5	2.0	15	12	15	1.3
Mass:	Boston	Oct	1.80	1.0	2.7	5	16	25	1.0
		Nov	1.67	1.0	3.2	5	17	40	1.0
		Dec	1.84	1.2	2.8	5	17	45	1.1
Mo:	St. Louis	Oct	NS	NS	NS	NS	NS	NS	NS
		Nov [a]	1.84	1.7	3.1	5	20	35	.9
		Dec [a]	1.54	1.2	2.8	5	12	15	.8
Ohio:	Cleveland	Oct	1.20	.8	2.0	5	8	25	.6
		Nov	1.08	.6	2.1	5	8	30	.6
		Dec	1.08	.6	1.9	5	8	15	.7
Pa:	Pittsburgh	Oct	2.17	1.1	3.0	5	30	55	2.0
		Nov	2.11	1.3	3.0	5	21	55	1.3
		Dec	2.14	1.3	2.8	5	19	45	1.1
S. C:	Charleston	Oct	1.57	.8	1.7	5	25	40	2.7
		Nov	1.49	.9	2.1	5	16	45	NA
		Dec	2.03	1.4	2.8	5	28	50	2.4
S. Dak:	Sioux Falls	Oct	NS	NS	NS	NS	NS	NS	NS
		Nov	(d)						
		Dec	1.24	.7	2.0	5	6	20	.9
Tex:	Austin	Oct	1.58	.9	2.2	NA	11	25	1.7
		Nov	1.48	.6	1.6	NA	10	5	NA
		Dec	1.72	.9	2.1	NA	12	35	1.7
Vt:	Burlington	Oct	1.35	.8	2.2	5	15	40	1.1
		Nov	1.42	.9	2.8	5	17	55	.7
		Dec [a]	1.32	1.1	2.1	5	13	40	1.3
Wash:	Seattle	Oct [a]	1.84	2.2	2.2	5	23	10	1.8
		Nov [a]	1.93	2.3	2.7	5	31	85	2.1
		Dec [a]	1.43	.9	2.6	5	10	55	.6
Institutional average		Oct	1.72	1.1	2.6	5	17	55	1.9
		Nov	1.62	1.0	2.4	5	20	45	1.4
		Dec	1.69	1.1	2.4	5	14	40	1.5

[a] Since food samples were collected from two or more children whose ages were unknown, data for this month were not used in the institutional average

[b] Since food samples were collected from two or more children who were less than 9 years of age, data for this month were not used in the institutiona average.

[c] Since food samples were collected from two or more children who were over 12 years of age, data for this month were not used in the institutional average.

[d] Total weight of sample is unknown since milk component of diet for Sioux Falls was not sent to laboratory. Intake values consequently could not be computed for this institution.

NA, no analysis.
NS, no sample.

analytical procedures was presented elsewhere (3).

Results

Table 1 presents the analytical results for institutional diet samples collected from October through December 1966, for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet, and the radionuclide concentrations of strontium-89, strontium-90, cesium-137, and radium-226 are expressed as pCi/kg of diet. The reported radionuclide concentrations of these samples are corrected for radioactive decay to the midpoint of the sample collection period, where applicable.

Dietary intakes, presented in table 2, were obtained by multiplying the food consumption rate in kg/day by the concentration values given in table 1. For the purpose of obtaining dietary intakes, "less than" 5 pCi/kg of strontium-89 was interpreted as 2.5 pCi/kg. The average food consumption rate during this period was 1.68 kg/day compared to the network average of 1.90 kg/day observed from 1961 through 1964 (*4*).

Strontium-90 dietary intake during this period averaged 17 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (*5*). Cesium-137 intakes averaged 47 pCi/day during this period. Strontium-89, barium-140, and iodine-131 concentrations were generally below detectable levels.

REFERENCES

(*1*) ANDERSON, E. C., and D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391-1400 (September 1962).

(*2*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January-March 1965. Radiol Health Data 6:548-554 (October 1965).

(*3*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, April-June 1965. Radiol Health Data 7:92-96 (February 1966).

(*4*) GRUNDY, R. D., C. CALVERT, and A. G. BERGER. Summary of results of Institutional Total Diet Sampling Network, 1961-1964. Radiol Health Data 6:691-696 (December 1965).

(*5*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
1965 Annual Averages	July 1966
January-March 1966	October 1966
April-June 1966	January 1967
July-September 1966	April 1967

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclides intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when more complete analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the safe limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water programs previously reported in *Radiological Health Data and Reports* are listed below.

Program	Period reported	Last presented
California Water Sampling	January–June 1966	June 1967
Coast Guard Water Sampling	1965	November 1966
Colorado River Basin Sampling Network	1962–1964	November 1965
Drinking Water Analysis	1962	October 1965
Florida Water Sampling	1964	November 1965
Kentucky Water Sampling	May 1963–June 1964	March 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Minnesota Surface Water Sampling	January–June 1966	January 1967
New York Surface Water Sampling	June–December 1965	June 1966
North Carolina Water Sampling	1964	November 1965
Radiostrontium in Tap Water	March–November 1966	June 1967
Washington Surface Water Sampling	July 1964–June 1965	May 1966

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Gross Radioactivity in Surface Waters of the United States, January 1967

Division of Pollution Surveillance Federal Water Pollution Control Administration Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha- and beta-particle analyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium-90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports*.

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioacivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly

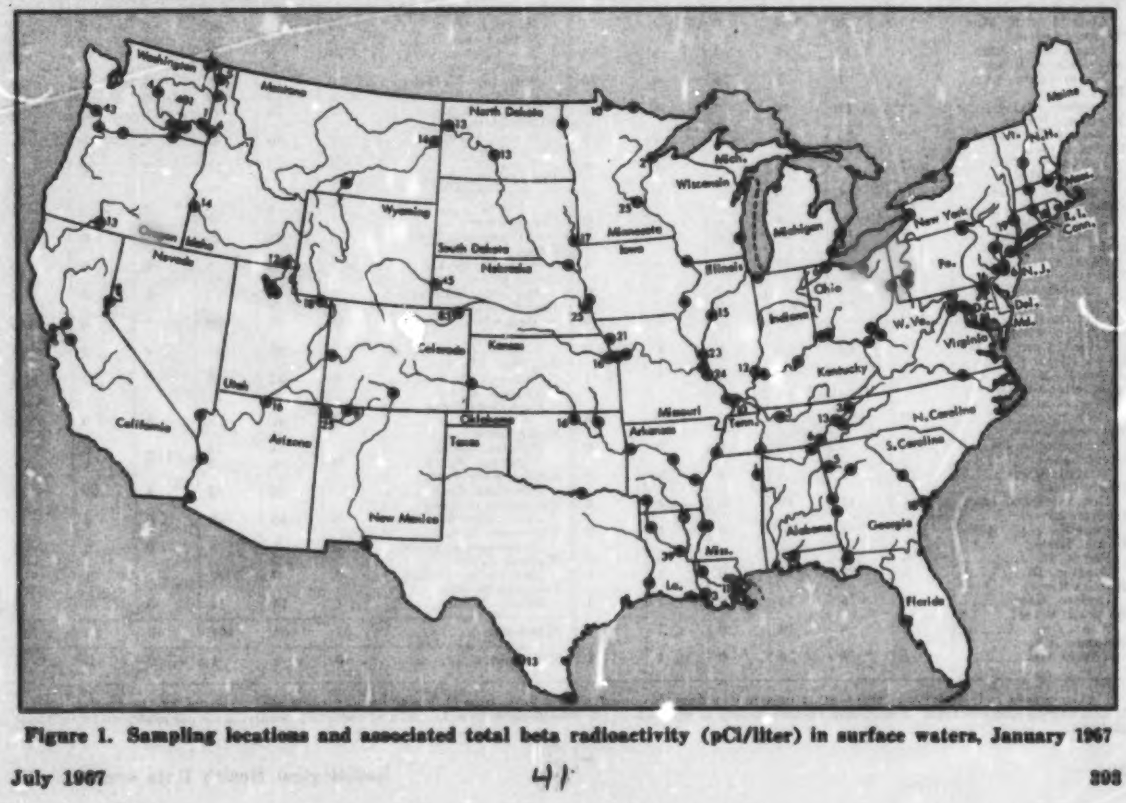
Washington
Montana
North Dakota
Minnesota
Wisconsin
Mich.
Michigan
New York
Vt.
N.H.
Maine
Mass.
R.I.
Conn.
N.J.
Pa.
Del.
Md.
D.C.
Ohio
Indiana
Illinois
Iowa
South Dakota
Wyoming
Oregon
Idaho
Nevada
Nebraska
Colorado
Kansas
Utah
California
Arizona
New Mexico
Oklahoma
Texas
Missouri
Arkansas
Kentucky
W. Va.
Virginia
N. Carolina
S. Carolina
Tenn.
Georgia
Alabama
Miss.
La.
Florida

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, January 1967

average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both December 1966 and January 1967, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved or suspended solids:

Atchafalaya River; Morgan City, La;
North Platte River; Henry, Nebr;
South Platte River; Julesburg, Colo.

During January, at Cedar Hill, N. Mex., on the Animas River, alpha radioactivity dropped to less than 15 pCi/liter on suspended solids. Pasco, Wash., on the Columbia River continued to show beta radioactivity on dissolved solids in excess of 150 pCi/liter.

REFERENCES

(1) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(2) *Ibid.*, 1959 Edition.
(3) *Ibid.*, 1960 Edition.
(4) *Ibid.*, 1961 Edition.
(5) *Ibid.*, 1962 Edition.
(6) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table 1. Radioactivity in raw surface waters, January 1967

Station	Average beta radioactivity (pCi/liter)			Average alpha radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	1	8	9	0	1	1
Arkansas River:						
Ponca City, Okla.	1	15	16	0	4	4
Atchafalaya River:						
Morgan City, La.	3	< 1	3	16	9	25
Bear River:						
Preston, Idaho	0	12	12	0	3	3
Big Sioux River:						
Sioux Falls, S. Dak.	2	15	17	< 1	2	2
Chena River:						
Fairbanks, Alaska	1	2	3	0	0	0
Clearwater River:						
Lewiston, Idaho	2	4	6	0	0	0
Clinch River:						
Clinton, Tenn.	0	3	3	0	0	0
Kingston, Tenn *	2	11	13	0	1	1
Colorado River:						
Page, Ariz.	1	15	16	0	4	4
Columbia River:						
Wenatchee, Wash.	0	4	4	0	0	0
Pasco, Wash *	37	364	401	0	< 1	< 1
Clatskanie, Ore.	10	33	43	0	0	0
Connecticut River:						
Enfield Dam, Conn.	6	12	18	0	0	0
Coosa River:						
Rome, Ga.	2	3	5	< 1	0	< 1
Cumberland River:						
Cheatham Lock, Tenn.	0	3	3	0	0	0
Delaware River:						
Philadelphia, Pa.	1	5	6	0	0	0
Great Lakes:						
Duluth, Minn.	0	2	2	0	0	0
Green River:						
Dutch John, Utah	1	17	18	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	6	13	19	0	0	0
Illinois River:						
Peoria, Ill.	5	10	15	1	2	3
Grafton, Ill.	0	23	23	0	1	1
Kansas River:						
DeSoto, Kans.	1	15	16	0	1	1
Klamath River:						
Keno, Ore.	5	8	13	0	< 1	< 1
Maumee River:						
Toledo, Ohio	1	5	6	0	1	1
Mississippi River:						
St. Paul, Minn.	6	19	25	0	0	0
E. St. Louis, Ill.	5	19	24	0	0	0
New Orleans, La.	3	8	11	1	1	2
Missouri River:						
Williston, N. Dak.	0	13	13	0	3	3
Bismarck, N. Dak.	< 1	13	13	0	3	3
St. Joseph, Mo.	2	19	21	0	4	4
North Platte River:						
Henry, Nebr.	2	43	45	0	26	26
Ohio River:						
Cairo, Ill.	3	7	10	1	0	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	1	4	5	0	< 1	< 1
Platte River:						
Plattsmouth, Nebr.	3	22	25	1	6	7
Potomac River:						
Washington, D.C.	1	5	6	0	0	0
Rainy River:						
Baudette, Minn.	0	10	10	0	0	0
Red River, South:						
Alexandria, La.	11	28	39	0	0	0
Rio Grande:						
Laredo, Tex.	1	12	13	0	5	5
San Juan River:						
Shiprock, N. Mex.	8	17	25	2	7	9
Savannah River:						
Port Wentworth, Ga *	8	10	18	1	0	1
Snake River:						
Payette, Idaho	2	12	14	0	6	6
Wawawai, Wash.	0	1	1	0	1	1
South Platte River:						
Julesburg, Colo.	23	60	83	4	29	33
Susquehanna River:						
Conowingo, Md.	6	10	16	0	0	0
Tennessee River:						
Chattanooga, Tenn.	3	3	6	0	0	0
Wabash River:						
New Harmony, Ind.	3	9	12	1	1	2
Yellowstone River:						
Sidney, Mont.	1	13	14	0	5	5
Maximum	37	364	401	16	29	33
Minimum	0	< 1	1	0	0	0

* Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides common to all stations.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data.* In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
HASL Fallout Network	July–December 1965	September 1966
	Calendar year 1965	January 1967
HASL 80th Meridan Network	October–December and	
National Air Sampling Network	annual summary 1966	April 1967
Plutonium in Airborne Particulates	October–December 1966	May 1967

1. Radiation Surveillance Network
March 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity made by the station operators after decay of radon and thoron daughter products prior to submission of the samples for laboratory analysis. When high air levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during March 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Gross beta radioactivity in air and precipitation decreased to near normal levels during March.

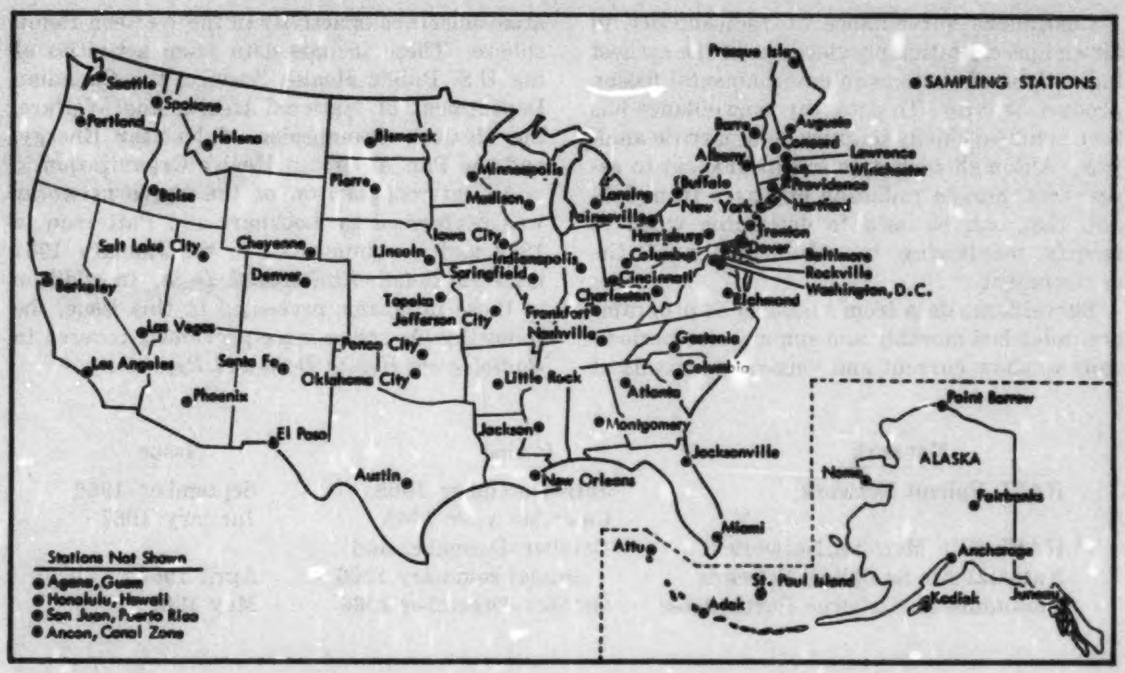
● SAMPLING STATIONS
Seattle
Spokane
Portland
Helena
Bismarck
Pierre
Minneapolis
Madison
Boise
Salt Lake City
Cheyenne
Lincoln
Iowa City
Indianapolis
Springfield
Denver
Berkeley
Topeka
Jefferson City
Frankfort
Nashville
Las Vegas
Ponca City
Oklahoma City
Los Angeles
Santa Fe
Phoenix
Little Rock
El Paso
Jackson
Austin
New Orleans
Montgomery
Atlanta
Jacksonville
Miami
Gastonia
Columbia
Charleston
Richmond
Cincinnati
Columbus
Lansing
Painesville
Buffalo
Harrisburg
New York
Trenton
Dover
Baltimore
Rockville
Washington, D.C.
Albany
Barre
Augusta
Concord
Presque Isle
Lawrence
Winchester
Providence
Hartford
ALASKA
Point Barrow
Nome
Fairbanks
Anchorage
Kodiak
Juneau
Attu
Adak
St. Paul Island
Stations Not Shown
Agana, Guam
Honolulu, Hawaii
San Juan, Puerto Rico
Ancon, Canal Zone

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1967

Station location		Number of samples		Air surveillance, gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	31	4	0.36	0.04	0.16	Nov 66	48	< 9
Alaska:	Adak	31		.33	.00	.11	Jun 67	(b)	
	Anchorage	16	4	.40	.03	.12	Dec 66	9	< 2
	Attu Island	17		.13	.01	.06	Jul 67	(c)	
	Fairbanks	(c)					Jan 67	(b)	
	Juneau	31	6	.18	.01	.06	Apr 67	167	<37
	Kodiak	8		.34	.03	.13	May 67	(b)	
	Nome	(c)					Sep 66	(b)	
	Pt. Barrow	26		.14	.05	.10	Aug 66	(c)	
	St. Paul Island	(c)					Oct 66	(c)	
Ariz:	Phoenix	31		.63	.11	.29	Apr 67	(b)	
Ark:	Little Rock	30	6	.41	.06	.15	Dec 66	78	<15
Calif:	Berkeley	25	9	.31	.06	.15	May 67	140	<28
	Los Angeles	25	4	.41	.05	.18	Sep 66	30	<12
C. Z.:	Ancon	18		.06	.01	.05	May 67	(b)	
Colo:	Denver	31	2	.37	.10	.21	May 67	17	< 3
Conn:	Hartford	31	10	.40	.04	.17	Apr 67	93	<19
Del:	Dover	22		.30	.01	.14	Nov 66	(b)	
D. C.:	Washington	27	8	.34	.01	.12	Aug 66	107	<22
Fla:	Jacksonville	30	2	.30	.03	.15	Dec 66	17	< 3
	Miami	30	4	.35	.04	.15	Apr 67	113	<23
Ga:	Atlanta	31	6	.43	.04	.19	Oct 66	58	<13
Guam:	Agana	31		.11	.00	.04	Nov 66	(b)	
Hawaii:	Honolulu	31	4	.23	.01	.09	Jul 67	168	<34
Idaho:	Boise	27	2	.45	.01	.17	Jul 67	10	< 2
Ill:	Springfield	27	4	.33	.02	.11	Aug 66	70	<14
Ind:	Indianapolis	30	7	.41	.03	.16	Oct 66	88	<18
Iowa:	Iowa City	31	6	.37	.03	.15	May 67	50	<10
Kans:	Topeka	31	4	.33	.03	.16	Dec 66	29	< 5
Ky:	Frankfort	31	6	.35	.03	.16	Aug 66	51	<10
La:	New Orleans	30	4	.40	.04	.18	Aug 66	31	< 6
Maine:	Augusta	30	7	.30	.05	.16	Sep 66	37	< 7
	Presque Isle	31		.30	.07	.14	May 67	(b)	
Md:	Baltimore	23	6	.33	.01	.14	Apr 67	43	< 9
	Rockville	31	3	.31	.01	.13	Jul 67	99	<20
Mass:	Lawrence	30	5	.36	.03	.17	Nov 66	53	<11
	Winchester	19	6	.60	.02	.20	Jun 67	94	<19
Mich:	Lansing	30		.35	.02	.16	Jul 67	(b)	
Minn:	Minneapolis	21	5	.21	.05	.12	Nov 66	21	< 4
Miss:	Jackson	30	3	.32	.03	.12	Sep 66	43	< 9
Mo:	Jefferson City	31	3	.34	.03	.14	Oct 66	41	< 8
Mont:	Helena	27	5	.35	.08	.16	Jun 67	30	< 8
Nebr:	Lincoln	22	1	.49	.03	.17	Oct 66	19	< 4
Nev:	Las Vegas	29		1.01	.03	.36	Jan 67	(b)	
N. H.:	Concord	30		.32	.04	.15	Aug 66	(c)	
N. J.:	Trenton	31	9	.37	.01	.12	Sep 66	34	< 7
N. Mex:	Santa Fe	28	3	.61	.04	.15	Jun 67	15	< 3
N. Y.:	Albany	25	6	.32	.04	.16	Oct 66	46	< 9
	Buffalo	23		.30	.04	.11	May 67	(b)	
	New York City	29		.37	.01	.14	Jun 67	(c)	
N. C.:	Gastonia	31	5	.41	.06	.19	May 67	61	<13
N. Dak:	Bismarck	31	4	.26	.04	.13	Aug 66	6	< 1
Ohio:	Cincinnati	30		.32	.05	.18	Nov 66	(b)	
	Columbus	29	8	.44	.07	.20	Sep 66	99	<20
	Painesville	30	9	.29	.03	.15	Apr 67	41	< 9
Okla:	Oklahoma City	30	6	.19	.07	.12	Jul 67	47	<10
	Ponca City	27	3	.12	.03	.06	Apr 67	23	< 4
Ore:	Portland	30	23	.24	.02	.09	Oct 66	121	<24
Pa:	Harrisburg	30	2	.35	.02	.11	Oct 66	83	<17
P. R.:	San Juan	25	2	.31	.03	.14	Sep 66	28	< 6
R. I.:	Providence	26	6	.28	.03	.13	Jul 67	87	<18
S. C.:	Columbia	26	4	.41	.05	.17	Jun 67	73	<15
S. Dak:	Pierre	31		.31	.06	.15	Apr 67	(b)	
Tenn:	Nashville	31	4	.26	.04	.13	Jul 67	96	<19
Tex:	Austin	30	4	.30	.06	.16	Nov 66	22	< 4
	El Paso	31	2	.64	.05	.21	Aug 66	4	< 1
Utah:	Salt Lake City	31	5	.79	.11	.29	Sep 66	44	< 9
Vt:	Barre	29	6	.31	.06	.16	Dec 66	21	< 4
Va:	Richmond	31	8	.46	.06	.14	Dec 66	64	<13
Wash:	Seattle	30	15	.15	.02	.06	Dec 66	71	<14
	Spokane	31	5	.30	.05	.13	Nov 66	23	< 5
W. Va:	Charleston	31	10	.37	.02	.14	Jun 67	156	<31
Wis:	Madison	28	4	.32	.01	.11	Dec 66	44	< 9
Wyo:	Cheyenne	31	4	.29	.07	.17	Jan 67	15	< 3
Network summary		1,928	306	1.01	0.00	0.15	....	59	<12

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of 0.005 or less are reported and used in averaging as 0.00 pCi/m³.

[b] No precipitation sample collected.

[c] No report received.

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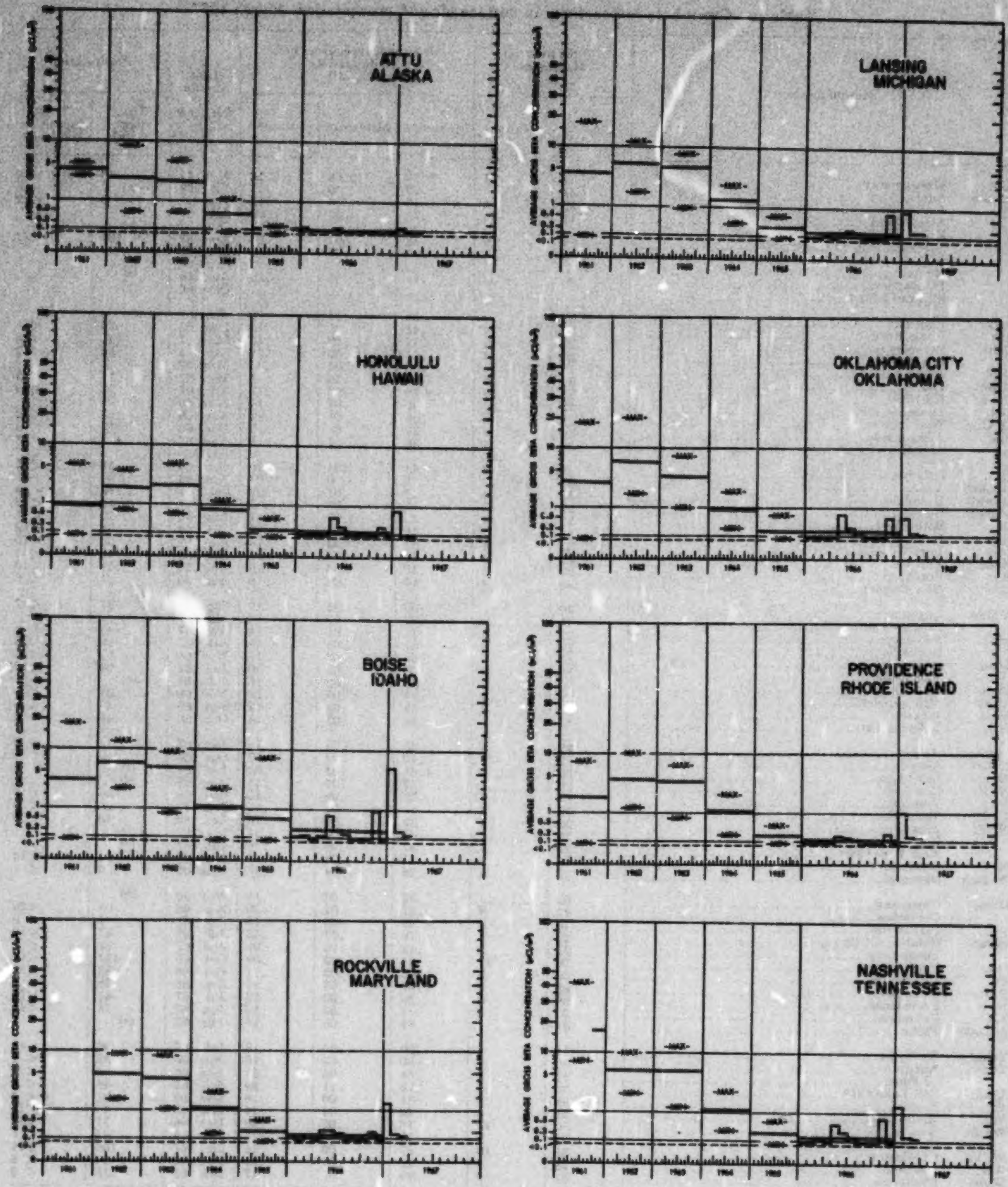

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1961–March 1967

2. Canadian Air and Precipitation Monitoring Program, March 1967[1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for March 1967 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, March 1967

Station	Number of samples	Air surveillance radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.1	0.2	53	1.0
Coral Harbour	30	.2	.0	.1	11	.5
Edmonton	31	.3	.1	.2	15	.5
Ft. Churchill	31	.2	.1	.1	26	.5
Ft. William	31	.3	.1	.2	66	1.8
Fredericton	31	.4	.1	.2	79	3.7
Goose Bay	31	.2	.1	.1	60	1.0
Halifax	31	.3	.0	.2	10	1.3
Inuvik	30	.2	.1	.1	16	.4
Montreal	30	.5	.0	.2	70	4.4
Moosonee	31	.3	.1	.2	30	1.0
Ottawa	31	.4	.1	.2	318	8.0
Quebec	31	.3	.1	.2	82	2.4
Regina	22	.3	.1	.2	42	1.2
Resolute	31	.2	.0	.1	NS	NS
St. John's, Nfld	31	.3	.0	.1	14	1.4
Saskatoon	30	.3	.0	.1	12	.5
Sault Ste. Marie	31	.3	.0	.2	74	2.5
Toronto	31	.4	.0	.2	32	.8
Vancouver	31	.2	.0	.1	9	.8
Whitehorse	31	.3	.0	.2	26	.5
Windsor	31	.4	.0	.2	57	1.5
Winnipeg	31	.3	.1	.2	46	.8
Yellowknife	31	.2	.1	.1	32	.4
Network summary	731	0.5	0.0	0.2	52	1.6

NS, no sample.

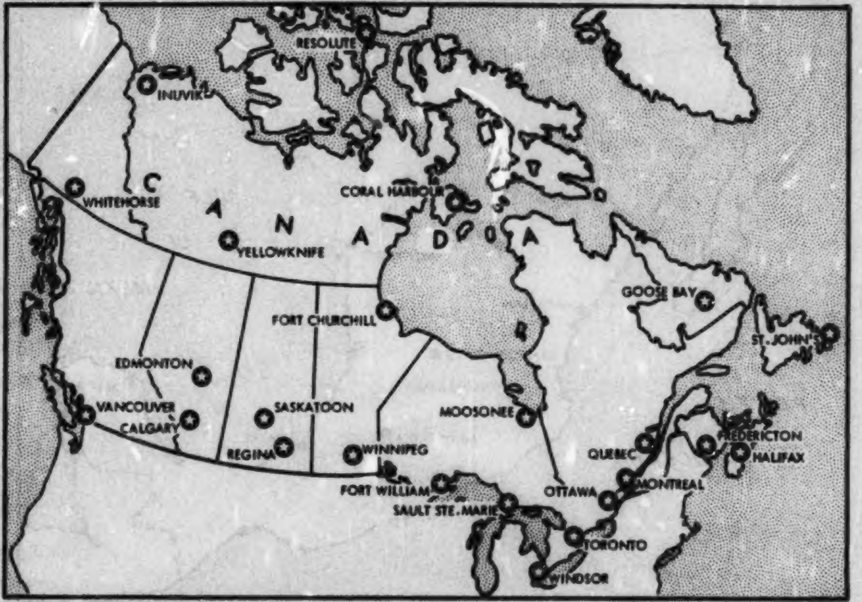
RESOLUTE
INUVIK
WHITEHORSE
C A N A D A
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
MONTREAL
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

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[1] Prepared from information and data in the April 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

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3. Mexican Air Monitoring Program
March 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Instituto de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of eight samples per month were needed to get a reliable average activity at each station (*7*).

The maximum, minimum, and average fission product beta concentrations in surface air during March 1967 are presented in table 3.

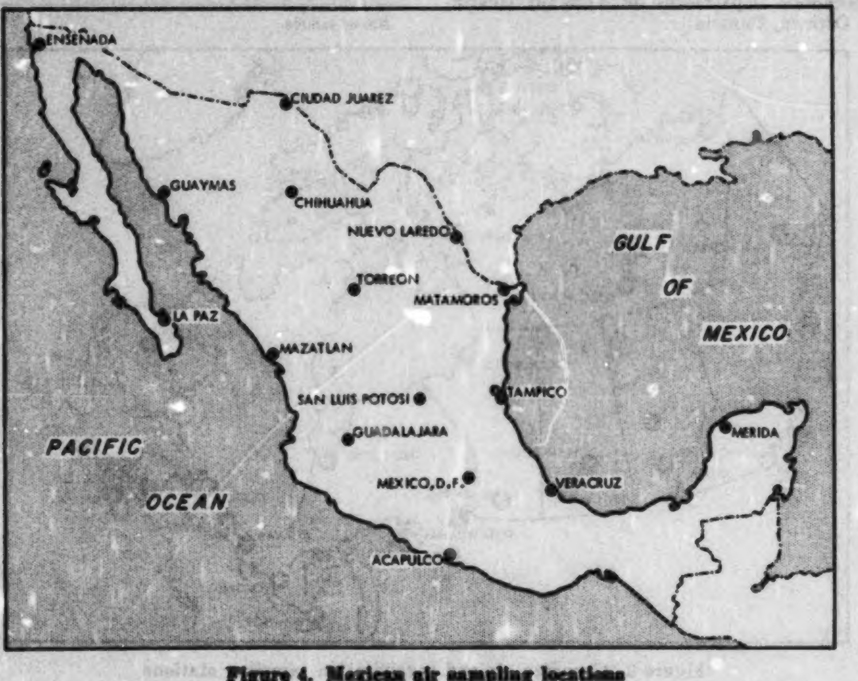

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, March 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	13	0.4	0.1	0.2
Chihuahua	15	1.1	<0.1	.3
Ciudad Juárez	15	.5	.1	.3
Ensenada	5	.5	.1	.3
Guadalajara	3	.1	.1	.1
Guaymas	NS			
La Paz	7	.7	.1	.4
Matamoros	NS			
Mazatlán	10	1.1	.1	.5
Mérida	9	.2	.1	.1
México, D.F.	15	.3	<0.1	.1
Nuevo Laredo	8	.4	.1	.3
San Luis Potosí	NS			
Tampico	15	.2	.1	.1
Torreón	12	1.0	<0.1	.5
Veracruz	NS			

NS, no sample collected, station temporarily shutdown.

4. Pan American Air Sampling Program March 1967

Pan American Health Organization and U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station positions are shown in figure 5.

The March 1967 air monitoring results from the participating countries are given in table 4. No fresh fission products were identified on PAHO air samples during March.

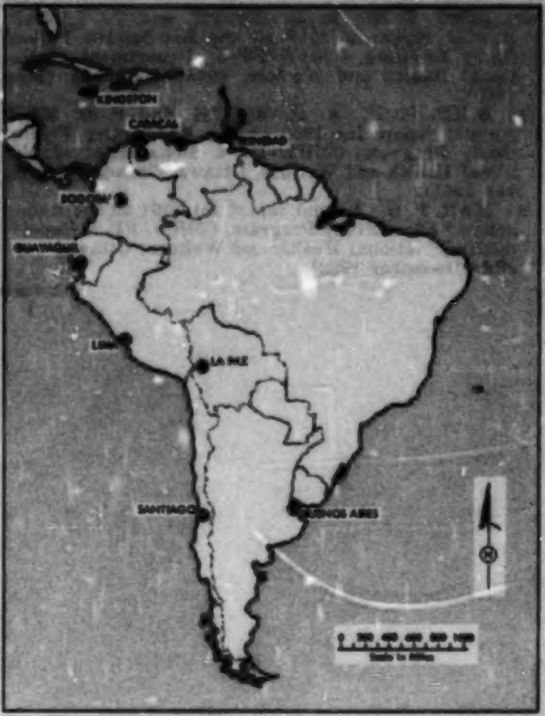

Figure 5. Pan American Air Sampling Program stations

Table 4. Gross beta radioactivity in surface air PAHO, March 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	17	0.13	0.03	0.07
Bolivia: La Paz	NS			
Colombia: Bogota	35	.08	.02	.04
Chile: Santiago	22	.06	.00	.02
Ecuador: Guayaquil	25	.05	.01	.03
Jamaica: Kingston	17	.14	.04	.08
Peru: Lima	16	.05	.02	.03
Venezuela: Caracas	17	.11	.00	.06
West Indies: Trinidad	21	.09	.02	.06
Pan American summary	161	0.14	0.00	0.05

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of 0.005 pCi/m³ or less are reported and used in averaging as 0.00 pCi/m³

NS, indicates no report received.

REFERENCES

(*1*) RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Public Health Service, Washington, D.C. 20201 (Distribution by official request).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(3) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(4) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(5) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(6) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(7) VASQUEZ, M., and R. M. De NULMAN. Estudios sobre la radioactividad ambiental en la República Mexicana, 1960–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiológica (en prensa 1966).

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, July–September 1966[1]

National Center for Radiological Health
Public Health Service

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium-90 in measurable amounts has been present in the global environment for more than a decade and major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown their bone strontium-90 content to be low and age-independent (*1*).

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

Most specimens received to date have been vertebrae and ribs. Efforts to collect long bones for comparison of results with British data have not been successful.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the National Center for Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by TBP extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproductibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium-90) are analyzed periodically and cross-check analyses are carried out quarterly with the Health and Safety Laboratory of the AEC, which performs similar analyses.

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[1] Period during which death or surgical procedure occurred.

The analytical results for strontium-90 in individual bones from persons dying during the third quarter (July–September) of 1966 along with other pertinent data (place of residence, sex, bone type, and cause of death), are presented in table 1 in order of increasing age within each geographical sampling region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per gram of ash (the primary determination), per gram of calcium (for comparison with other data and for purposes of model development), and per gram of bone (as a rough indication of dose). Two-sigma counting errors are reported for the ash concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–4*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
First quarter 1966	February 1967
Second quarter 1966	March 1967

REFERENCES

(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64–1 (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone. Radiol Health Data 5:620–628 (December 1964).

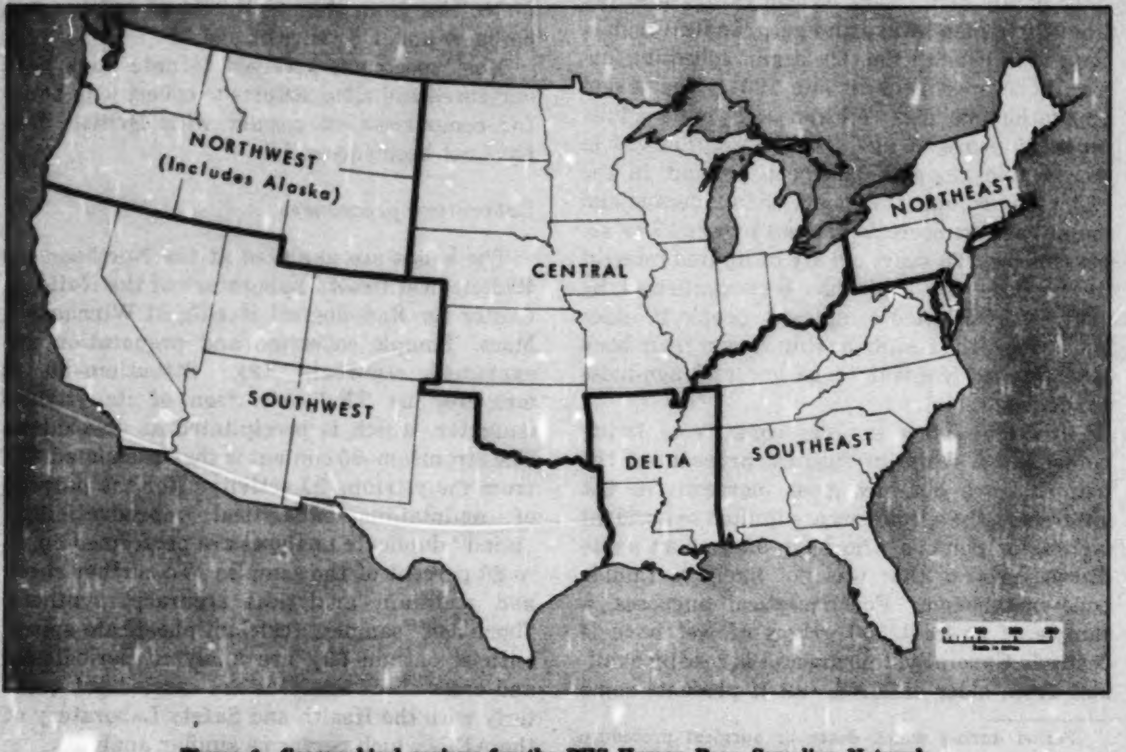

Figure 1. Geographical regions for the PHS Human Bone Sampling Network

Table 1. Strontium-90 in human bone, deaths and surgical procedures during July–September 1966

Sampling region and state of residence	Sex	Bone type [a]	Age at death [b] (years)	Cause of death	Strontium-90 pCi/g of:		
					Ash ±2σ error	Calcium	Bone
NORTHEAST:							
Mass.	M	V	2	Hydrocephalus	1.12 ±0.10	3.06	0.16
Mass.	F	V	2	Head injuries	1.51 ± .12	3.33	.13
Mass.	M	V	3	Meningococcemia	1.27 ± .15	3.65	.10
Vt.	M	V	5	Tetralogy of Fallot	1.35 ± .16	3.94	.11
Mass.	F	V	6	Acute leukemia	1.15 ± .15	3.30	.10
Pa.	F	V	8	Encephalitis	.77 ± .11	2.06	.07
N.Y.	M	V	8	Acute leukemia	.80 ± .11	2.23	.05
Mass.	F	V	8	Tracheobronchitis	.75 ± .14	3.18	.08
Mass.	F	V	9	Rheumatic heart disease	1.19 ± .10	3.38	.12
Pa.	M	V	9	Multiple injuries	.71 ± .05	1.96	.07
N.H.	F	V	10	Tetralogy of Fallot	1.34 ± .10	3.33	.12
Vt.	M	V	11	Degenerative brain disease	1.16 ± .12	3.19	.09
Maine	F	V	11	Aplastic anemia	.71 ± .08	1.85	.07
N.Y.	F	V	11	Subdural hematoma	.94 ± .08	2.46	.10
Mass.	F	V	12	Mitral regurgitation	.77 ± .07	2.05	.09
N.H.	M	V	12	Chronic renal disease	1.88 ± .11	5.28	.19
N.Y.	M	V	12	Carcinoma of testis	1.34 ± .09	3.65	.12
Mass.	M	V	14	Multiple injuries	1.38 ± .08	3.75	.13
Mass.	M	V	15	Lymphosarcoma	.91 ± .08	2.43	.11
Pa.	F	V	15	Death during surgery	1.40 ± .10	3.75	.22
N.Y.	M	V	16	Acute leukemia	.97 ± .07	2.58	.11
N.H.	M	V	16	Acute subdural hematoma	.86 ± .07	2.30	.12
N.Y.	M	V	17	Neuroblastoma	1.13 ± .10	3.01	.12
Mass.	M	V	18	Fracture of femur	.81 ± .08	2.11	.11
Mass.	F	V	18	Myelomeningocele	.94 ± .09	2.65	.12
N.J.	F	V	18	Multiple injuries	.67 ± .08	1.74	.09
Pa.	M	V	19	Asphyxiation	.91 ± .12	2.37	.15
Vt.	M	V	19	Drowning	.97 ± .08	2.60	.13
Vt.	F	V	20	Gunshot wound of head	.80 ± .08	2.10	.11
Vt.	M	V	22	Traumatic hemothorax	.78 ± .08	2.12	.08
N.Y.	M	V	24	Carcinoma of testis	.74 ± .07	1.95	.10
Mass.	F	V	25	Coronary artery disease	1.11 ± .10	3.01	.12
CENTRAL:							
Wis.	F	V	1	Tricuspid atresia	1.81 ±0.18	4.32	.14
Wis.	F	V	2	Cardiac fibroelastosis	1.84 ± .21	4.42	.15
Wis.	F	V	2	Tetralogy of Fallot	1.58 ± .22	4.00	.13
Wis.	F	V	3	Acute leukemia	.86 ± .15	3.85	.09
Minn.	M	V	3	Ruptured liver and spleen	1.48 ± .11	4.01	.14
Ohio	M	V	3	Viral encephalitis	.65 ± .05	1.95	.05
Ohio	M	V	4	Acute leukemia	1.00 ± .11	2.91	.08
Wis.	M	V	4	Encephalitis	.31 ± .05	0.88	.08
Ohio	F	V	4	Vascular malformation	1.25 ± .11	3.36	.12
Wis.	M	V	4	Congenital heart disease	1.00 ± .14	3.05	.11
Wis.	F	V	5	Encephalitis	.89 ± .11	3.39	.08
Wis.	M	V	5	Glomerulonephritis	.54 ± .07	1.51	.08
Wis.	F	V	11	Death during surgery	.71 ± .09	2.08	.10
Ohio	M	V	15	Intracranial hemorrhage	1.11 ± .08	2.91	.15
Ohio	M	V	18	Traumatic hemothorax	.81 ± .05	2.10	.10
Wis.	M	V	19	Sickle cell anemia	.87 ± .11	2.33	.09
Mo.	M	S	20	Head injuries	.74 ± .13	3.06	.09
DELTA:							
Tex.	F	V	1	Bacterial meningitis	1.08 ±0.06	3.16	.09
La.	M	V	3	Acute leukemia	2.29 ± .21	6.51	.16
La.	F	V,R	3	Cor biloculare	3.61 ± .19	9.55	.41
La.	M	V	9	Lymphoblastic leukemia	1.03 ± .15	2.91	.08
([d])	F	V	12	([d])	1.35 ± .10	3.60	.17
La.	M	V	18	Guillain-Barré syndrome	1.39 ± .09	3.58	.19
La.	F	V	23	Glomerulonephritis	1.06 ± .10	2.77	.12
Tex.	F	V	25	Endometritis	.38 ± .06	1.01	.05
NORTHWEST:							
Wash.	M	V	13	Acute leukemia	0.93 ±0.09	2.40	.12
Ore.	M	V	15	([d])	.39 ± .05	1.05	.04
Alaska	M	R	16	([c])	1.69 ± .18	4.42	.46
Ore.	M	V	18	Head injury	.71 ± .07	1.87	.11
Ore.	M	V I, SK	19	Multiple injuries	.86 ± .07	2.24	.20
Ore.	F	V	20	Cervical spine injury	.65 ± .07	1.69	.08
Ore.	F	V	24	Diabetic acidosis	.69 ± .06	1.83	.08

[a] Type of bone:
R, rib
V, vertebrae
S, sternum
I, illium
SK, skull

[b] Age given as of last birthday prior to death.

[c] Sample obtained from surgical procedure.

[d] Information not yet available.

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Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Paducah Plant, Pinellas Peninsula Plant, and the Shippingport Atomic Power Station.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

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1. Paducah Plant
July–December and Calendar Year 1966[2]

Union Carbide Corporation
Paducah, Kentucky

The Paducah Plant is a Government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant (a former source of diffusion plant feed) was placed on standby in June of 1964. Parts of the associated uranium metal foundry are operated infrequently as the need arises; otherwise, it is also on a standby status. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium-234 and protactinium-234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probably biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Because of the necessity for health protection in process areas, the high intrinsic value of uranium, and the desire to maintain a wholesome relationship with neighboring communities and individuals, the Paducah Plant provides confinement and recovery systems at the plant. The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 1). Big Bayou Creek water is sampled continuously, and grab samples are collected at five locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant

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[2] Summarized from "Environmental Concentrations of Radioactive Materials near the Paducah Plant—Report for the Year and Second Half of 1966."

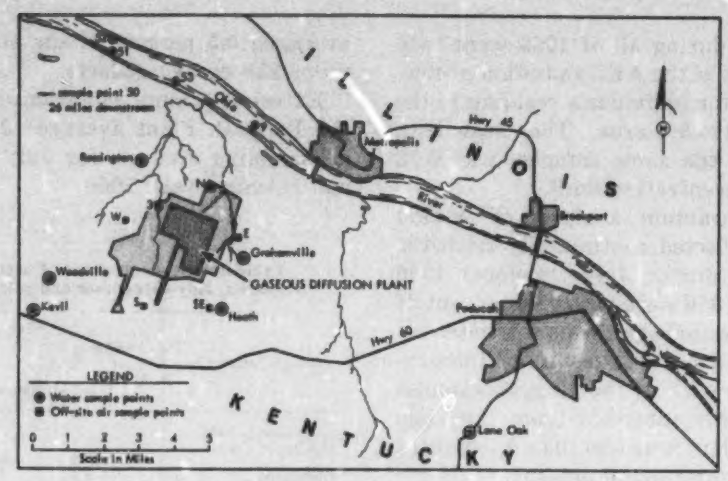

Figure 1. Sampling locations, Paducah Gaseous Diffusion Plant

work environment or employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year, and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radioisotopes in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 1 through 4.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

The average alpha particle count—interpreted as uranium, the most likely source of radioactivity—of the 234 air samples collected during July–December 1966, and the 467 air

Table 1. Uranium concentrations in outdoor air samples Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Uranium alpha [b] (pCi/m³)		
		Maximum	Minimum [c]	Mean [d]
July–December 1966: At plant perimeter fence:				
North	26	0.10	<0.02	<0.02
East	26	.17	< .02	< .02
South	26	.14	< .02	< .02
West	26	.06	< .02	< .02
Total, July–December 1966	104	0.17	<0.02	<0.02
Total, 1966	208	0.17	<0.02	<0.02
July–December 1966: About 1 mile outside plant perimeter fence:				
North	26	0.06	<0.02	0.02
East	26	.12	< .02	.02
South	26	.20	< .02	<0.02
West	26	.10	< .02	.02
Southeast	26	.13	< .02	.02
Total, July–December 1966	130	0.20	<0.02	0.02
Total, 1966	259	0.20	<0.02	<0.02

[a] See map in figure 1.

[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha particle disintegrations/second.

[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.

[d] The AEC radiation protection standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

samples collected during all of 1966 were both less than 1 percent of the AEC radiation protection standard set for individuals residing in the vicinity of a controlled area. The mean beta particle count of the same samples was 0.02 percent of the concentration limit.

The average uranium analysis of weekly water samples collected continuously from the Big Bayou Creek during July–December 1966 and during all of 1966 were both 0.05 percent of the radiation protection standards for water beyond a controlled area. The results of the uranium analyses for each of the 12 grab samples collected at monthly intervals from the Ohio River below the plant was less than 0.1 percent of the radiation protection standard.

Table 2. Beta radioactivity in outdoor air samples Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum[b]	Mean [c]
July–December 1966: At plant perimeter fence:				
North	26	0.93	<0.1	0.20
East	26	.74	< .1	.18
South	26	.95	< .1	.18
West	26	.95	< .1	.16
Total, July–December 1966	104	0.95	<0.1	0.18
Total, 1966	208	1.2	<0.1	0.21
July–December 1966: About 1 mile outside plant perimeter fence:				
North	26	0.79	<0.1	0.18
East	26	.89	< .1	.20
South	26	1.4	< .1	.23
West	26	.86	< .1	.18
Southeast	26	.90	< .1	.21
Total, July–December 1966	130	1.4	<0.1	0.20
Total, 1966	259	1.9	<0.1	0.19

[a] See map in figure 1.
[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³
[c] The AEC radiation protection standard, applicable to this table is 1×10^3 pCi/m³, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

The concentration of beta-particle emitters in the Big Bayou Creek averaged 0.5 percent of the radiation protection standard for the decay products of uranium–238 during July–December 1966; the average for the year was 0.5 percent of the standard. The beta radioactivity of the Ohio River was at or below the minimum detectable level during July–December 1966, and the results of all samples during the year averaged 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hour at all sampling stations for July–December 1966 and calendar year 1966.

Table 3. Concentrations of uranium in water Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Uranium [b] (pCi/liter)		
		Maximum	Minimum[c]	Mean [d]
July–December 1966:				
Big Bayou Creek 3	26	70	<1	10
Ohio River	6	1	<1	< 1
Composite of 50, 51, 52, and 53	6	1	<1	< 1
Year 1966:				
Big Bayou Creek 3	52	70	<1	10
Ohio River 9	12	1	<1	< 1
Composite of 50, 51, 52, and 53	12	1	<1	< 1

[a] See map in figure 1.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha particle disintegrations/second.
[c] The minimum detectable uranium in water is 1 pCi/liter.
[d] The AEC radiation protection standard for natural uranium in water beyond a controlled area is 2×10^4 pCi/liter.

Table 4. Concentration of beta-particle emitters in water Paducah, July–December and calendar year 1966

Sample location [a]	Number of samples	Beta particle emitters (pCi/liter)		
		Maximum	Minimum[b]	Mean [c]
July–December 1966:				
Big Bayou Creek 3	26	100	<100	<100
Ohio River 9	6	400	<100	200
Composite of 50, 51, 52, and 53	6	100	<100	<100
Year 1966:				
Big Bayou Creek 3	52	600	<100	100
Ohio River 9	12	200	<100	100
Composite of 50, 51, 52, and 53	12	500	<100	100

[a] See map in figure 1.
[b] The minimum detectable amount of beta particle emitters in water is 100 pCi/liter.
[c] The AEC radiation protection standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December and Calendar year 1965	July 1966
January–June 1966	January 1967

2. Pinellas Peninsula Plant
July–December 1966[3]

General Electric Company
St. Petersburg, Florida

Pinellas Peninsula Plant, shown in figure 2, is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous nonoccupational exposure established by AEC and documented in the "AEC Manual."

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily near the perimeter of the plant's property. During the sampling period, 11 of 183 samples analyzed showed detectable concentrations of tritium (90 x 10^4 pCi/liter).[4] The maximum concentration (4.1 x 10^6 pCi/liter) which was detected on August 22, 1966, amounted to 137 percent of the continuous nonoccupational exposure guide. Calculations based on radioactivity releases from the process waste system, and the plant's water discharges, indicate that the average tritium concentration in the combined sewer effluent for July–December 1966 was less than 7.0 percent of the AEC radiation protection standard for continuous nonoccupational exposure.

Air monitoring

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the two samples collected during the sampling period revealed no detectable

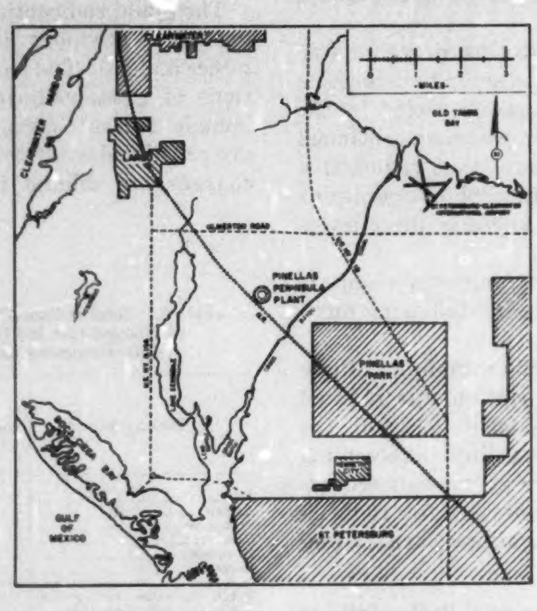

Figure 2. Location of the Pinellas Penisula Plant

amounts of tritium gas (9.6 x 10^{8} pCi/m^{3}) or tritium oxide (5.0 x 10^{8} pCi/m^{3}).

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[3] Summarized from "Environmental Monitoring, July 1 through December 31, 1966" General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Fla.

[4] Expressions in parenthesis indicate limits of detectability in the respective environmental samples.

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium oxide (9.0 x 10^{4} pCi/liter) in the 45 surface water samples analyzed during the sampling period.

Milk sampling results

Eighteen samples of raw milk were collected from local dairy farms and analyzed by the Florida State Board of Health during July–December 1966. No detectable concentrations (9.0 x 10^{4} pCi/liter) of tritium were evident.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	August 1966
January–June 1966	February 1967

3. Shippingport Atomic Power Station July–December and Calendar Year 1966[5]

Duquesne Light Company
Shippingport, Pennsylvania

The Shippingport Atomic Power Station is operated for the Atomic Energy Commission by the Duquesne Light Company. The plant site is located near Shippingport, Pennsylvania, along the Ohio River about 25 miles northwest of Pittsburgh (figure 3).

An environmental monitoring program was begun 2 years before plant startup to determine the background levels of radioactivity in the environment. This program was then continued after plant startup to ensure that radioactive waste discharges from normal plant operations do not cause significant changes in these levels in the plant environment.

In January 1966, the environmental monitoring program was revised in the following manner:

1. Fallout and precipitation sampling at three locations surrounding the station was reduced to one sample taken at one onsite location.
2. The continuously recording beta-gamma radiation monitors and the continuously recording airborne particulate monitors for radioactivity situated at three locations surrounding the station were eliminated. For monitoring significant airborne releases of radioactivity in case of an accident, 12 film badges were located surrounding the station and changed on a quarterly frequency.
3. The sampling of river sediment upstream and downstream of the station's outfall was commenced on a quarterly basis.

Liquid radioactive waste disposal

The liquid radioactive wastes discharged during July–December 1966 are summarized in tables 5 and 6. The monthly average concentrations of gross radioactivity shown in table 5 include normal background radioactivity and are calculated after total radioactive waste discharges are diluted in the condenser-cooling

Table 5. Total radioactive waste, exclusive of tritium, discharged into the Ohio River, Shippingport July–December and calendar year 1966

Period 1966	Total discharge (mCi)	Average discharge (mCi/day)	Average concentration in effluent channel (pCi/liter)
July	2.05	0.066	1.34
August	3.96	.128	1.80
September	2.90	.097	0.57
October	10.18	.3[illegible]	3.94
November	6.63	.2[illegible]	3.94
December	3.35	.1[illegible]	2.94
Total discharge and grand average, July–December	29.07	0.158	2.04
Calendar year 1966	56.3	0.15	2.38

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[5] Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Station for the Second Half of 1966 and Calendar Year 1966" PNR–SMD–141.

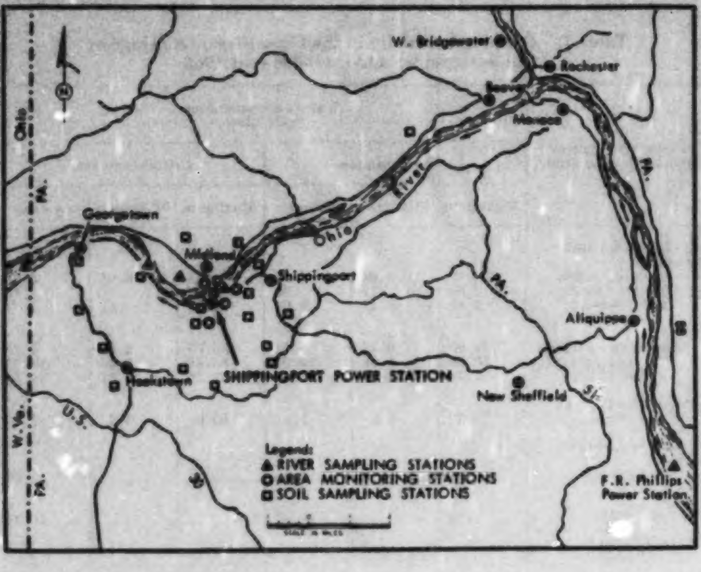
W. Bridgewater
Rochester
Beaver
Monaca
Ohio
PA.
Georgetown
Midland
Shippingport
Ohio
River
PA.
Aliquippa
PA.
SHIPPINGPORT POWER STATION
Hookstown
New Sheffield
U.S.
W. Va.
PA.
Legend:
▲ RIVER SAMPLING STATIONS
○ AREA MONITORING STATIONS
□ SOIL SAMPLING STATIONS
F.R. Phillips Power Station

Figure 3. Shippingport power station sampling locations

water effluent channel. The maximum total discharge in 1 day during July–December 1966 was 1.33 millicuries.

Table 6 is a summary of the tritium that was discharged into the Ohio River, the monthly average concentration of tritium in the holdup tanks prior to discharge, and monthly average concentration of the waste in the effluent channel after dilution with the condenser-cooling water. The maximum quantity of tritium discharge in 1 day during July–December 1966 was 586 millicuries.

Automatic samplers are installed at the station's river water influent and effluent to collect water samples continuously for comparative purposes. The continuous samples were analyzed for gross beta and gross alpha radioactivities in the suspended and dissolved solids. The potassium–40 radioactivity in the total solids of these samples was also measured. No significant difference was observed between the average alpha-particle, beta-particle and potassium–40 radioactivity in the influent and effluent samples. The results of these analyses are shown in table 7.

Table 6. Tritium released to Ohio River, Shippingport July–December and calendar year 1966

Period 1966	Total discharge (mCi) (multiply by 10^3)	Average discharge (mCi/day)	Average concentrations in hold-up tanks (nCi/liter) (multiply by 10^4)	Average concentrations in effluent channel (nCi/liter)
July	2.01	64.9	1.86	2.96
August	3.02	97.5	2.17	2.36
September	2.11	70.4	1.58	1.[illegible]
October	5.30	171.0	1.28	3.66
November	3.41	114.0	1.49	3.92
December	2.54	81.9	1.34	3.87
Total discharge and grand average, July–December	18.4	100.0	1.52	2.66
Calendar year 1966	27.3	74.9	....	2.10

Atmospheric releases of radioactive materials

During July–December 1966, a total of 293 μCi of xenon–133 was released at Shippingport at concentrations less than the MPC of 3 x 10^5 pCi/m^3. The incinerator, which is used for burning combustible contaminated waste was not operated.

Environmental monitoring

Twelve beta-gamma sensitive film badges which were posted around the station boundary to determine external radiation levels again showed faulty results. The density readings for the background control films were greater than the density for the environmental films during July–December 1966. Three modifications have been incorporated in the Shippingport procedures in an effort to solve the present problems.

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Table 7. Gross radioactivity in the Ohio River, Shippingport July–December and calendar year 1966

Period and type of radioactive material	Average concentration (pCi/liter)					
	Influent samples			Effluent samples		
	Maximum	Minimum	Average	Maximum	Minimum	Average
July–December 1966:						
Alpha:						
Suspended solids	0.40	0.04	0.18	0.51	0.03	0.20
Dissolved solids	3.33	.17	.86	2.00	.11	.92
Total solids	3.45	.24	1.03	2.35	.34	1.11
Beta:						
Suspended solids	81.88	0.22	6.61	34.75	0.22	5.79
Dissolved solids	70.89	1.94	12.06	25.86	1.46	13.75
Total solids	152.73	4.66	18.66	59.16	3.54	19.54
Potassium-40:						
Total solids	10.5	3.5	7.9	10.0	3.6	7.6
Calendar year 1966:						
Alpha:						
Total solids			1.03			1.04
Beta:						
Total solids			16.43			15.74
Potassium-40:						
Total solids			6.3			6.1

(1) A change was made in the film-badge packaging technique. (2) One-month exposures will be tried at some of the perimeter stations to indicate if the length of the exposure period affects the exposure rate. The present exposure period is one calendar quarter. (3) The control film will be packaged and mounted at some unaffected location offsite to help compensate for natural environmental conditions as a film effect. Past control films have been stored in the darkroom throughout the exposure period.

River sediment samples were collected from the Ohio River once each calendar quarter upstream and downstream from the station's liquid waste outfall. These samples were analyzed for gamma-ray activity, and quantitated assuming all detected radioactivity to be cobalt-60, which is the major constituent of radioactive contamination at the station. Concentrations of radioactivity in the sediment for the third and fourth calendar quarters were, respectively, 9.24 and 8.79 pCi/g upstream and 9.68 and 9.55 pCi/g downstream from the outfall. These results indicate that there was no appreciable increase of radioactivity in the river sediment as the result of the station's discharges of radioactive contaminated liquid wastes.

Radioactive fallout was collected in a pot at one onsite location and analyzed weekly for alpha and beta radioactivity. The average quarterly and semiannual results are depicted in table 8.

Table 8. Radioactivity in fallout, Shippingport July–December and calendar year 1966

Period	Deposition rate ($nCi/m^2/month$)	
	Alpha radioactivity	Beta radioactivity
Third quarter 1966	0.13	4.08
Fourth quarter 1966	.34	7.18
July–December, 1966	.24	5.63
Calendar year 1966	.32	13.32

Summary

During July–December 1966 and for the calendar year 1966, measurements of radioactivity were made in the Ohio River and in the vicinity of the Shippingport Atomic Power Station. The results of these measurements indicate that the radioactive material released by the power station into the Ohio River did not result in a significant change in the naturally occurring radioactivity in the environment.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	July 1966
January–June 1966	February 1967

SECTION V. TECHNICAL NOTES

Reported Nuclear Detonations, June 1967

The Atomic Energy Commission announced on June 17 that the Chinese detonated a nuclear device at their Lop Nor site. The yield was in the range of several megatons. This is the sixth Chinese nuclear test confirmed by the United States.

Three underground nuclear tests of low yield (less than 20 kilotons TNT equivalent) were conducted by the U.S. Atomic Energy Commission at its Nevada Test Site on June 22, 26 and 29, respectively. The test of June 22 was part of the Plowshare program which is part of an effort to develop nuclear devices experimentally designed for peaceful purposes. This test is one of a series to develop devices for use in possible later excavation experiments.

There was a small release of radioactivity from the June 29 test. While most of this radioactivity was deposited within the Test Site, very low levels of radioactivity have been detected on the ground near the Site. The highest of these was 0.7 milliroentgen per hour in an unpopulated area about three miles from the boundary of the Government-controlled reservation. This reading dropped to near background levels within an hour. This level of radioactivity presents no health hazard.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

DISTRIBUTION OF STRONTIUM AND CALCIUM IN MAJOR VEGETABLE AND FRUIT CROPS AND CRITERIA FOR USE OF FALLOUT-CONTAMINATED FOODS. *J. W. Ralls, S. Primbsch, T. R. Guckeen, H. J. Maagdenberg, J. Rinehart, F. C. Lamb, and W. A. Mercer. Radiological Health Data and Reports, Vol. 8, July 1967, pp. 355–358.*

Vegetable and fruit crops were grown in soil enriched with high levels of strontium nitrate. The normally edible portions of the crops were harvested and sectioned into anatomically distinct portions. The strontium and calcium content was measured by flame spectrophotometry or by photon activation analysis. The results are tabulated to provide an upper limit for radiostrontium content of crops grown in soil heavily contaminated with debris from nuclear fission on a massive scale.

KEY WORDS: calcium, crops, decontamination, fruits, strontium-90, strontium to calciun ratio, vegetables

AERIAL MEASUREMENT OF THE KIWI TRANSIENT NUCLEAR TEST. *R. D. Coleman and V. E. Andrews. Radiological Health Data and Reports, Vol. 8, July 1967, pp. 359–366.*

The Los Alamos Scientific Laboratory conducted a Transient Nuclear Test on a KIWI Reactor on January 12, 1965, at the Nuclear Rocket Development Station at Jackass Flats, Nev. During this planned destructive test of a propulsion reactor, the Public Health Service's Southwestern Radiological Health Laboratory conducted a land and aerial offsite radiological surveillance program. The aerial aspects of the Laboratory's program include sampling and assay missions along flight patterns through the radioactive cloud formed by the destruction of the reactor. Samples obtained from these aerial missions were analyzed to define various characteristics of the cloud. The decrease of peak gamma-ray readings with distance from the site of the experiment was exceptionally rapid. The reduction is attributed to a combination of decay and excellent meteorological diffusion.

KEY WORDS: aerial, cloud, KIWI Transient Nuclear Test, nuclear reactor, radioactive release, radionuclides

SUMMARY OF POPULATION EXPOSURE TO X-RAYS IN THE UNITED STATES, 1964. *Population Studies Program, National Center for Radiological Health, Radiological Health Data and Reports, Vol. 8, July 1967, pp. 367–378.*

A summary of the highlights of *Population Exposure to X-rays, U.S., 1964, A Report on the Public Health Service X-Ray Exposure Study*, PHS Publication No. 1519 is presented. It is estimated that 58 percent of the 187 million civilian noninstitutional population of the United States had one or more X-ray visits. The estimated annual dental X-ray rate declined from 27.4 per 100 persons in 1961 to 26.8 in 1964. The estimated annual rate of medical X-ray visits increased from 47.9 per 100 persons in 1961 to 49.8 in 1964. Of the 173 million X-ray examinations or procedures performed during these visits, 105 million were radiographic, 54 million dental, 10.5 million fluoroscopic, and 3.5 million X-ray therapy. The estimated number of X-ray films taken were 506 million.

KEY WORDS: dental X-rays, fluoroscopy, medical X-rays, population exposure, X-rays

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Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results, and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature, a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs, whenever possible.

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References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 8, Number 8, August 1967

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

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Atomic Energy Commission

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Strontium-90 in Human Bones, 1964–1965

R. M. Hallisey and *M. A. Wall*[1]

Results obtained from analysis of strontium–90 in human bone specimens from 303 individuals who died in 1964, and 293 individuals who died in 1965 have been studied. The bone specimens were collected at autopsies in selected metropolitan cities throughout the United States. A summary table of all the data for deaths occurring in 1964 and 1965 is presented. In most of the five age groups in 1965, average values are slightly lower than the 1964 values. Regional variations in the strontium–90 to calcium ratio are shown with the highest average for each year in the Delta region. The data were related to human bone concentrations that were derived from the Federal Radiation Council's Radiation Protection Guides and intake ranges, and it was shown that in both years the average bone concentrations correspond to Range I of these intake guides.

In the latter part of 1961, the National Center for Radiological Health (then the Division of Radiological Health) of the Public Health Service initiated an investigation into the levels of strontium–90 in human bones. This project was a continuation of a study by Kulp and Schulert at the Lamont Geological Laboratory which was terminated in 1961 (*1*). Previous papers have reported results on samples from deaths occurring through 1963 (*2–4*). This present paper summarizes the results of analyses of human bone specimens from 303 individuals who died in 1964, and 293 individuals who died in 1965. The analytical data on these 596 specimens have appeared in previous issues of *Radiological Health Data and Reports* (*5*).

Bone specimens from autopsies are collected by pathologists, medical examiners, and coroners in selected metropolitan cities throughout the United States (figure 1). For comparison purposes, concentrated collection efforts are maintained around five principal cities; namely, Boston, Mass.; Cincinnati, Ohio; New Orleans, La.; Seattle, Wash.; and Los Angeles, Calif. With the exception of a few samples obtained at surgical procedures, the specimens are limited to those obtained from accident victims or persons who have died of an illness not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount of bone is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. The population group of particular interest is infants and young adults up to 25 years of age. Most of the bone specimens involved in this report are vertebrae or ribs.

Analytical procedure

The bones are analyzed at the Northeastern Radiological Health Laboratory, Winchester, Mass., a field laboratory of the National Center for Radiological Health. Before analysis, the specimens are ashed in two stages, the final stage being at 800° C. in aluminum oxide crucibles. In the original procedure, a fraction containing yttrium–90, in equilibrium with its parent, strontium–90, was separated from the bone ash by extraction with 2-thenoyltrifluoroacetone (TTA). Starting with the 1964 samples, the procedure was changed so that the yttrium is purified by tributyl phosphate (TBP) extractions.

A suitable portion of bone ash (5 to 10 grams) is dissolved in 1:1 nitric acid. Stron-

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[1] Mr. Hallisey is presently chief, X-ray Project and Mrs. Wall is a statistician at the Northeastern Radiological Health Laboratory, Winchester, Mass. 01890.

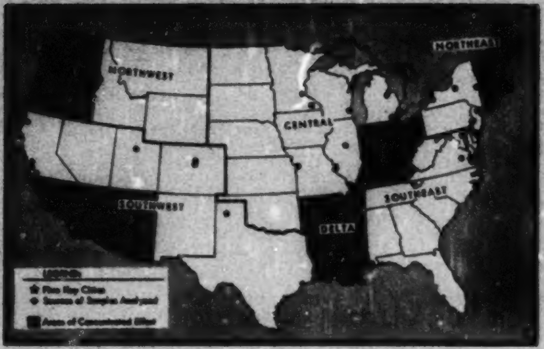

Figure 1. Regions for PHS Bone Sampling Network

tium and yttrium carriers are added. Fuming nitric acid is added to precipitate strontium and separate the strontium–90 from its daughter, yttrium–90. The yttrium–90 is purified by extraction into tributyl phosphate, and back extracted into dilute nitric acid. It is then concentrated by precipitation as the oxalate, dried, weighed to determine chemical recovery, and counted for beta radioactivity in a low-background beta-particle counter. With the application of proper decay and chemical recovery factors, the yttrium–90 activity is calculated. Because the strontium–90 and yttrium–90 are in equilibrium, the determined yttrium–90 activity is an indirect measurement of the strontium–90 concentration (*6*).

This procedure is an adaption of a previously reported procedure (*7,8*). It yields results comparable to those obtained by the TTA procedure, is shorter, and requires essentially no platinumware. The purity of the yttrium–90 is checked by decay measurements over several half-lives. A number of human bone samples were analyzed by both methods and an analysis of variance of the data showed no significant difference between the results of the two methods.

For the purpose of maintaining analytical quality control, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. In addition, "spiked" synthetic bone ash samples have been prepared and are analyzed routinely. Through the Analytical Quality Control Service of the National Center for Radiological Health, a cross-check program with the Health and Safety Laboratory of the Atomic Energy Commission is conducted monthly. Preliminary results of the first 6 months of this program show satisfactory agreement between the two laboratories.

Results

A summary of these data is presented in table 1. In each of the five age groups, the 1965 average values are generally slightly lower than the 1964 values. However, the highest single bone concentration (11.7 pCi/g of calcium) was reported for an 8-month old child in 1965 in the southwestern region of the United States. On the average, the levels in the Southwest region are consistently lower than those of any of the other five regions. The combined regional averages for 1964 and 1965 are shown in figure 2. This figure indicates definite regional variations in the strontium–90/calcium ratio in human bone among the six regions. For each year tested, the Delta region had the highest average and the Southwest region had the lowest average. This relationship is consistent with that observed for strontium–90 in the pasteurized milk and institutional diet networks as reported in previous issues of *Radiological Health Data and Reports.*

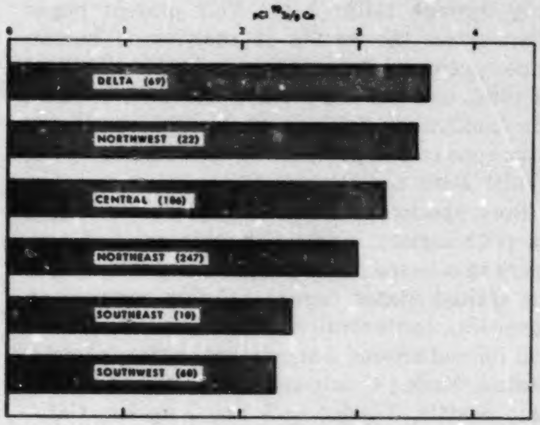

Figure 2. Combined data regional averages, 1964 and 1965

The frequency distribution for strontium–90 in human bone specimens in the years of 1964 and 1965 is shown in figure 3. The strontium–

Table 1. Strontium-90 in human bones by year of death, age and region (pCi strontium-90/g calcium)

Region	0–4 years				5–9 years				10–14 years				15–19 years				20–24 years				Total number
	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	No.	Max	Min	Mean	
1964 deaths																					
Northeast	17	8.4	2.6	5.0	30	7.0	1.2	3.6	37	5.7	1.5	3.3	31	5.4	1.2	2.0	33	3.9	0.8	2.2	148
Southeast	NS	NS	NS	NS	NS	NS	NS	NS	1	NA	NA	2.3	1	NA	NA	2.7	1	NA	NA	2.1	3
Central	35	8.7	1.8	4.7	21	6.2	1.7	3.8	6	4.0	1.8	2.8	12	4.7	1.3	2.3	11	3.4	1.0	2.0	85
Delta	3	6.7	3.7	5.4	5	5.4	2.9	4.2	4	4.9	2.9	3.5	10	5.1	2.0	3.6	4	4.3	1.5	2.8	26
Northwest	1	NA	NA	3.2	2	5.2	4.3	4.7	1	NA	NA	5.6	2	6.1	2.7	4.4	4	3.9	0.6	2.3	10
Southwest	12	5.0	1.0	2.7	6	3.4	1.4	2.4	7	3.4	0.9	2.1	2	2.0	2.0	2.0	4	3.0	1.6	2.4	31
All regions	68	8.7	1.0	4.4	64	7.0	1.2	3.6	56	5.7	0.9	3.1	58	6.1	1.2	2.9	57	4.3	0.6	2.2	303
1965 deaths																					
Northeast	16	8.9	2.4	3.9	21	5.5	2.1	3.4	17	3.8	0.9	2.7	27	3.5	1.5	2.4	20	2.8	1.3	2.1	101
Southeast	NS	NS	NS	NS	2	3.0	2.5	2.7	NS	NS	NS	NS	3	2.6	2.2	2.3	2	2.8	1.9	2.4	7
Central	32	7.8	1.4	4.2	16	5.9	1.4	2.6	17	5.2	1.5	2.6	17	3.8	1.3	2.2	19	2.6	1.0	1.8	101
Delta	16	10.2	2.8	5.2	7	6.4	2.6	3.8	9	3.5	1.1	2.7	5	2.9	1.3	1.9	6	3.0	1.0	2.1	43
Northwest	3	5.7	3.3	4.5	2	2.8	1.7	2.3	3	4.4	2.7	3.4	3	4.7	1.8	3.6	1	NA	NA	1.3	12
Southwest	14	11.7	0.7	2.6	6	3.6	1.3	1.9	2	2.3	2.3	2.3	3	2.5	1.5	2.1	4	1.5	1.0	1.2	29
All regions	81	11.7	0.7	4.1	54	6.4	1.3	3.0	48	5.2	0.9	2.7	58	4.7	1.3	2.3	52	3.0	1.0	1.9	293

NS, no samples collected.
NA, not applicable.

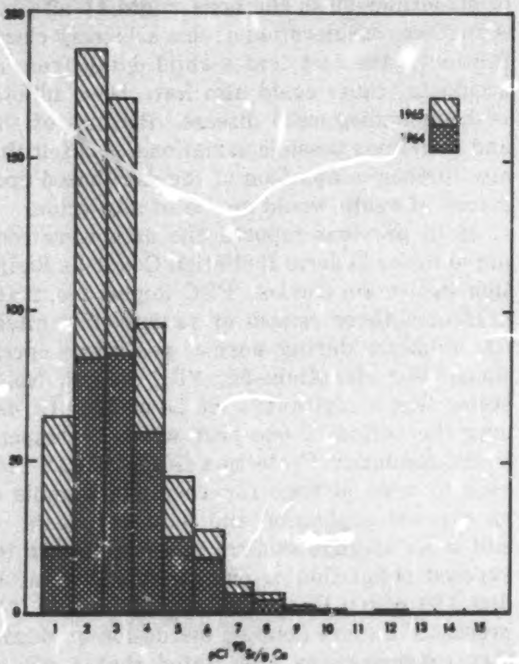

Figure 3. Frequency distribution for 1964 and 1965 deaths

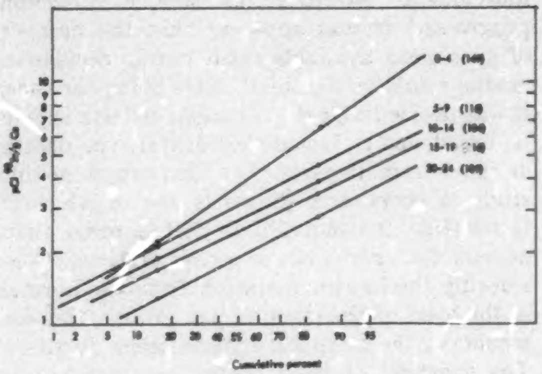

Figure 4. Strontium-90 to calcium ratios in human bone

90/calcium distribution is skewed for all 1964 and 1965 samples. Similar skewed distributions were obtained for each of the age groups for these years. As shown in previous papers (*3,4*), a logarithmic probability plot (figure 4) clearly indicates that the distribution is log normal, consistent with earlier observations of Kulp and Schulert (*1*) on whole skeleton samples obtained in New York. Similar logarithmic probability plots and frequency distributions are obtained when the data from other years are plotted.

Figure 5 is a plot of the median pCi of strontium-90/gram of calcium versus age for 1964 and 1965. Since the data are not normally distributed, it is felt that the median is the more significant value, although the mean value is useful in comparison with other data. With the exception of the 0- to 12-month group, the median values are higher for the 1964 bone specimens than for the 1965 specimens.

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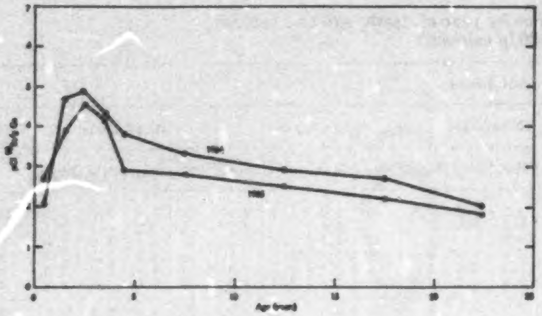

Figure 5. Median versus age

Discussion

In the original sampling protocol, it was decided that only specimens from accidental deaths would be analyzed, since these should more closely represent average values for living individuals. However, as sample collection progressed, it was apparent that the number of specimens available from purely accidental deaths would be too small. This being the case, it was decided that the sampling criteria should be broadened to include accidental type deaths or short-term illnesses. For the purpose of this study, a short-term illness is one in which it is felt that the individual's diet is other than normal for only a short period of time. Considering the known variation from the normal in the diets of the younger age groups, this extension of the sampling criteria seems justified. The shortage of bone specimens from purely accidental deaths may also be accounted for by the fact that in many areas of the country autopsies are not performed on young individuals who have died from obviously accidental causes. Taking the above facts into consideration, a large number of bone specimens from non-accidental deaths have been analyzed. For comparison purposes, the samples were placed in three arbitrary classifications according to the cause of death. The three classifications were as follows: (a) accidental deaths; (b) non-accidental deaths in which, in the normal course of the specific illness, calcium levels and kinetics are known to be not usually affected; (c) non-accidental deaths in which, in the course of the specific illness, calcium levels and kinetics may be affected.

In addition, the individuals[2] classifying the specimens were cognizant of the effect of extended disuse of bone on calcium kinetics. Autopsy specimens from persons whose illnesses inherently affected calcium levels and kinetics were eliminated. Once all specimens were classified, they were grouped by age at death and cause of death. An additional classification of specimens by region proved impracticable because of the small number of samples in some age/region/cause of death categories. An analysis of variance test was performed and no significant difference was observed in the strontium-90/calcium ratios among the age/cause of death categories.

Although it should be remembered that this classification is purely arbitrary, it still appears probable that the strontium-90/calcium ratios would not differ even though the total amount of strontium-90 in the bone might be affected. A further consideration of this arbitrary classification is the fact that a child dying from an accidental cause could also have been afflicted with an undiagnosed disease. Because of this and numerous possible variations, it is felt that any further comparison of the data based upon causes of death would not be of any value.

As in previous reports, the data were compared to the Federal Radiation Council's Radiation Protection Guides. FRC Report No. 2 (*9*) presented three ranges of radionuclide intake for guidance during normal peacetime operations. For strontium-90, FRC Report No. 2 stated that a continuous intake of 200 pCi/day over the period of one year would correspond to the Radiation Protection Guide of 0.17 rad/year to mineral bone for a suitable sample of an exposed population and that this would result in an average skeletal concentration in the exposed population of one quarter that in the diet (50 pCi/g Ca). FRC Report No. 7 (*10*) presented a more detailed discussion on dosimetry considerations and stated that 1 nCi of strontium-90 in adult bone would result in a dose of 2.7 rads/year to mineral bone. Therefore, the concentration corresponding to the Radiation Protection Guide of 0.17 rad/year would be 6.3 pCi/g Ca. FRC Report No. 7 also stated that the dose to mineral bone of the fetus and infant may be one-half that of the adult value because of less mineral content and less absorption of available beta-particle energy, resulting in a concentration of 126 pCi/g Ca corresponding to 0.17 rad/year. These values are summarized in table 2. The highest single value for an individual, 11.7 pCi of strontium-90 per gram of calcium, which was measured in the 0- to 4-year-age group in 1965, is within the gui[illegible] corresponding to Range I. Consideration of the averages within the five age groups for both 1964 and 1965 reveal that Range I was not exceeded. Because of unavoidable deficiencies in the sampling programs, especially the lack of samples from certain age groups in certain regions, no definite interferences on population averages can be made.

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[2] The bone specimens were classified on the basis of information from death certificates by Ronald Seltzer, M.D., a consultant from the Massachusetts General Hospital, and David E. P. Fitzpatrick, M.D., staff medical officer at the Northeastern Radiological Health Laboratory.

A comparison of the data from Germany, England, and the United States (Public Health Service and Atomic Energy Commission) is shown in table 3 (*11–14*) for 1963, 1964 and 1965. In general, the values are not dissimilar, allowing for the differences due to sampling techniques and geographic locations.

Table 2. Strontium-90 concentrations in mineral bone corresponding to Federal Radiation Council daily intake ranges, pCi/g calcium

FRC intake range [a] (pCi/day)	Population "average"			Individuals		
	FRC #2	FRC #7		FRC #2	FRC #7	
		Adults	Infants		Adults	Infants
I (0–20)	0–5	0–6.3	0–12.6	0–15	0–19	0–38
II (20–200)	5–50	6.3–63	12.6–126	15–150	19–190	38–380
III (200–2,000)	50–500	63–630	126–1,260	150–1,500	190–1,900	380–3,800

[a] Based on a radiation protection guide of 0.17 rad/year, which corresponds to the upper value of range II.

Table 3. Average strontium-90 levels in human bone, United States and Europe

Age group	Year	PHS	AEC [a]	Germany	England
0–4	1963	4.3 (44) [b]	3.6 (72)	3.7 (30)	4.7 (165)
	1964	4.4 (67)	3.6 (64)	5.4 (36)	7.9 (130)
	1965	4.1 (81)	4.3 (43)	5.9 (19)	7.9 (84)
5–19	1963	3.2 (163)	1.8 (64)	1.4 (27)	1.6 (74)
	1964	3.2 (178)	2.7 (67)	2.8 (28)	2.2 (46)
	1965	2.7 (160)	2.9 (58) [c]	2.7 (13)	2.8 (41)

[a] Average of tri-city study (New York City, Chicago, and San Francisco)
[b] Parentheses gives number of samples making up average.
[c] Chicago samples were not collected in 1965.

REFERENCES

(*1*) KULP, J. L., and A. R. SCHULERT. Strontium-90 in Man and His Environment, NYO-9934, Vol I-III (May 1962).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones (1961–1963) Radiol Health Data 5:231–239 May 1964).

(*3*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and E. J. BARATTA. Strontium-90 in human bone from infancy to adulthood, 1962–1963. Radiol Health Data Rep 7:383–386 (July 1966).

(*5*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Strontium-90 in human bone, October 1964–March 1965; 1962–64; First quarter 1965; April–June 1965; July–September 1965; October–December 1965. Radiol Health Data Rep 6:397–401 (July 1965); 7:243–246 (April 1966); 7:370–372 (June 1966); 7:529–531 (September 1966); 7:598–600 (October 1966); 7:727–729 (December 1966).

(*6*) BARATTA, E. J., and E. S. FERRI. Determination of strontium-90 in human bones by tributyl phosphate. Anal Chem 39:846–847 (June 1967).

(*7*) MAGNO, P. J., E. J. BARATTA, and E. S. FERRI. Procedures for the chemical and radiochemical analysis of environmental samples. NERHL-64-1, 2D-1. Winchester, Mass. 01890.

(*8*) VELTEN, R. J., and A. S. GOLDIN. Simplified determination of strontium-90. Anal Chem 33:128 (1961).

(*9*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*10*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium-89, strontium-90, and cesium-137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*11*) RIVERA, J. and J. HARLEY. The HASL bone program, 1961–1964, HASL-163. U.S. Atomic Energy Commission (August 16, 1965) p. 8.

(*12*) PRIBILLIA, O. and O. MUTSCHKE. Klinische Wochenschrift 43: Jahrging, 690–694 (June 12, 1965). Personal communication with Dr. Pribillia, January 11, 1965.

(*13*) MEDICAL RESEARCH COUNCIL MONITORING REPORT SERIES. Assay of strontium-90 in Human Bone in the United Kingdom, 1963–1965. Reports 8 through 13, England.

(*14*) Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Supplement No. 14 (A/6314), United Nations, New York (1966).

Uptake of Cesium-137 From Contaminated Soil by Selected Grass Crops

H. L. Cromroy,[1] *W. A. Goldsmith,*[1] *C. R. Phillips,*[2] and *W. P. Bonner*[1]

The cesium-137 content of milk in the Tampa, Fla. area has been consistently above the national average in recent years. The possibility that grasses grown in this area receive their contamination indirectly through contaminated soil is being investigated. Among the grasses investigated the uptake of cesium-137 appears to be greatest for pangola grass.

The cesium-137 content of milk in the Tampa, Fla. area has been consistently higher than the national average in recent years. This high concentration of cesium-137 has been reported to be related to the pangola grass feed received by dairy cows in this area (*1*). It is possible that grasses grown in this area received their contamination indirectly through contaminated soil, since direct deposition of fission products on the foliage would affect all hays equally, as indicated by Csupka *et al* (*2*).

The primary purpose of this investigation is to determine the difference in uptake of cesium-137 from contaminated soil by four hay crops (Tampa pangola, Gainesville pangola, Bahia, and Bermuda) indigenous to the State of Florida. If the uptake of cesium-137 by pangola grass is confirmed to be greater than the uptake by other grasses, the results may be useful for determining which grasses may be used as dairy feed without resulting in a high cesium-137 content in milk.

Procedure

The soil studied was obtained from a large dairy farm in the Tampa area on May 16, 1966. This soil was identified as Ona fine sand, belonging to the Scranton-Ona group which occurs on poorly drained, nearly level areas in northern and central Florida. Typical mechanical and chemical analyses of Ona fine sand are given in tables 1 and 2. The organic matter in this soil has a cation exchange capacity of less than 10 meq/100 g. The clay fraction has been identified as kaolinite (*3*). Kaolinite exhibits the properties of ion exchange and adsorption, but its interlayer spacing is not favorable for "structural adsorption." Thus, mass permanent fixation of cesium is not likely in this soil (*4–7*).

The soil samples were freed from the roots of pangola and weeds by shaking. After a thorough mixing, it was spread to a depth of about 5 inches in a 4- by 9-foot tray and subsequently divided into four plots, each 4 by 2¼ feet.

The three grasses chosen for this study represent grasses commonly used for pasture and hay in Florida. Pangola (*Digitaria decumbens*), Bermuda (*Cynodon dactylon*), and Bahia (*Paspalum notatum*), were obtained from plots under investigation by the Department of Agronomy at the University of Florida. These grasses were obtained by means of a core sampler on May 12, 1966 (2 days prior to the arrival of fallout from a recent surface burst on mainland China). All grasses were stored in the greenhouse prior to being sprigged into

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Table 1. Typical mechanical analysis of Ona fine sand [a]

Depth in inches	Moisture equivalent (percent) [b]	Very coarse sand (percent) [c]	Coarse sand (percent) [c]	Medium sand (percent) [c]	Fine sand (percent) [c]	Very fine sand (percent) [c]	Coarse silt (percent) [c]	Fine silt (percent) [c]	Clay (percent)
0–6	6.78	0.5	7.4	17.0	60.0	11.3	1.0	0.6	1.3
6–10	5.81	.9	7.0	16.3	59.6	11.6	3.3	.6	1.7
10–18	3.32	1.1	7.2	15.5	60.0	11.3	2.5	.7	1.7
18–42	2.15	.8	7.2	15.7	60.5	11.7	1.5	.4	1.8

[a] Reference (6).
[b] Percent of total weight.
[c] Percent of solids.

Table 2. Typical chemical analysis of Ona fine sand [a]

Depth in inches	Organic matter (percent)	Total nitrogen (percent)	Total phosphorous (percent)	Cation exchange capacity (meq/100g)	Exchangeable cation			
					Ca (meq/100 g)	K (meq/100 g)	Mg (meq/100 g)	Reaction pH
0–6	4.47	0.108	0.019	7.97	0.89	0.066	0.47	4.72
6–10	4.03	.080	.017	7.07	.12	.027	.08	5.22
10–18	.72	.021	.017	1.11	.08	.015	.03	5.45
18–42	.20	.009	.083	.60	.06	.008	.04	5.18

[a] Reference (6).

the Tampa soil on May 20, 1966. For comparison purposes, pangola grass from the Tampa area was also used.

Approximately 2 weeks later, the plots were treated with 10–10–10 commercial fertilizer at a rate equivalent to 300 pounds/acre, as recommended by the Department of Agronomy at the University of Florida. All foliage was cut to a height of 2½ inches on June 1, 1966. Optimum growing conditions were maintained by controlling the temperature between 80° to 90° F. with light watering each day except weekends. Grasses were cut to a height of 4 inches above the soil on June 28, 1966, and again on July 28, 1966, and subsequently analyzed to determine their cesium–137 concentration.

The uptake of cesium–137 by the soil was determined by means of a slurry test, similar to the procedure described by Lacy (*8*). The water for the slurry was spiked with enough cesium–137 to obtain a statistically valid total activity during a 2-minute counting period of a 2-milliliter sample. Preweighed amounts of dried soil were then added and the resulting suspensions were slurried by means of a magnetic stirring device. After 90 minutes of slurrying, the samples were filtered. Two-milliliter samples of the filtrate were then counted to determine the amount of cesium–137 which had been absorbed by the clay.

The samples of grass were counted in 1-liter Marinelli beakers. The counting system consisted of a right cylindrical sodium iodide (thallium activated) crystal with dimensions of 4 by 4 inches and a 400-channel pulse height analyzer.

The gamma-ray spectra were analyzed by a modified stripping technique in order to correct for interference from other gamma-emitting nuclides in the cesium–137 region. The daughters of radium–226 from the natural uranium decay chain present in the soil were the largest contributors of interfering radioactivity.

The grass samples were heated to 105° C. for 24 hours following counting. The concentration is reported in terms of this dry weight so that all values would be based on an equivalent moisture content.

Results

Cesium–137 uptake by Tampa soil (table 3) is much less than that reported by Straub (*9*) or Goldsmith (*10*) for other types of soil. However, the results reported in the literature were obtained on soils which contained almost 100 percent clay fraction (Tampa soils contain less than 5 percent). In addition, the soils investigated by Straub and Goldsmith contained clays which were generally montmorillonite or vermiculite which have high cation exchange capacities and adsorptive properties whereas kao-

Table 3. Average data for uptake of cesium-137 by Tampa soil

Sample	Clay dosage (mg/liter)	Influent activity (cpm/ml)	Effluent activity (cpm/ml)	Percent removal
1	[illegible]	5.06×10^5	3.66×10^5	28.3
2	2,012	4.88×10^5	3.42×10^5	29.9
3	3,010	4.87×10^5	3.33×10^5	31.5
4	4,[illegible]	5.54×10^5	3.74×10^5	32.5
5	5,[illegible]	6.02×10^5	4.09×10^5	32.0
6	7,010	6.17×10^5	4.08×10^5	34.3

limits found in Tampa soil is rather low in adsorptive capacity.

Since Tampa soil contains a small fraction of clay which has been identified as kaolinite, and no linear plot was obtained for an adsorption isotherm, it is most probable that if any uptake of cesium-137 by Tampa soil occurs, it is by an ion exchange process.

The cesium-137 concentrations in the various grasses as determined by counting on June 28 and July 28 are given in table 4 and 5, respectively. For unexplained reasons the growth of the Bermuda was retarded following transplantation. As a result, an insufficient sample was obtained on the second cutting for a statistically significant determination of its cesium-137 activity. Hence, no interpretation can be made of the data obtained from this grass.

Bahia appears to have matured more rapidly than pangola in this investigation. This was evidenced by the fact that the Bahia was in the anthesis stage of maturity while the Pangola was in the pre-early boot stage at the time of both cuttings.

Table 4. Concentration of cesium-137 in grasses on June 28

Grass	Cesium-137 radioactivity (pCi/kg dry weight)
Tampa pangola	[a]$(3.9 \pm .6)\times10^3$
Gainesville pangola	$(1.2 \pm .5)\times10^3$
Bahia	$(2.8 \pm .6)\times10^3$
Bermuda	$(1.3 \pm .6)\times10^3$

[a] Two σ counting error.

Table 5. Concentration of cesium-137 in grasses on July 28

Grass	Cesium-137 radioactivity (pCi/kg dry weight)
Tampa pangola	[a]$(4.2 \pm .8)\times10^3$
Gainesville pangola	$(2.7 \pm .7)\times10^3$
Bahia	$(2.8 \pm .6)\times10^3$
Bermuda	([b])

[a] Two σ counting error.

[b] Below detectable limits (because of the small amount of sample available.)

The concentration of cesium-137 varied from 1,296 to 4,220 pCi/kg (dry weight). The value for Tampa pangola is in agreement with that of Porter *et al* (*1*), for hay grown in the Tampa area. Although the concentration of cesium-137 in Gainesville pangola did not equal that of the Tampa pangola, the concentration more than doubled from the first to the second cutting, suggesting an approach to a stabilization level.

Tampa pangola had been growing in its native soil for several years and presumably had reached stabilization with the cesium-137, as evidenced by the negligible difference in the concentrations present in the two cuttings. Presumably, the cesium-137 concentration in Gainesville pangola would continue to increase until the cesium-137 concentration equaled that of the Tampa pangola.

It appears that the Bahia grass reached a stabilization concentration more rapidly than Gainesville pangola. This may be attributed to the more rapid rate of maturity observed for the Bahia grass.

Gammon (*11*) reports that the minimum potassium requirement for these grasses varies from 6 to 20 mg/kg of dry forage with pangola having the highest requirement followed by Bermuda and Bahia, in that order. The concentration of cesium-137 in the pangola and Bahia grass follows the potassium requirements as determined by Gammon. On this basis, a knowledge of the relative potassium requirements of plants provides a prediction of their relative cesium-137 uptake.

Conclusions

The current research gives some evidence that part of the cesium-137 content in the soil plots from the Tampa area is in an exchangeable form. There is also an indication that the uptake of cesium-137 by pangola is the most extensive among the grasses investigated.

Three areas of further study are suggested as a result of this investigation. First, a similar study for a much longer period of time in order to permit cesium-137 uptake by all grasses to reach a stabilization level would be valuable. Second, the effect of various fertilizers on the uptake of cesium-137 should be investigated.

Finally, other soil types and hay crops should be studied to be compared with the present studies.

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REFERENCES

(*1*) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida milk. Radiological Concentration Processes, B. Aberg and F. P. Hungate, Editors. Pergamon Press, New York, N.Y. (1967) p. 95.

(*2*) CSUKA, S., M. PETRASOVA, and J. CARACH. Seasonal variation in the concentration of cesium-137 in grass and alfalfa. Nature 213:1204-1206 (March 25, 1967).

(*3*) GAMMON, N., Jr., J. R. HENDERSON, R. A. CARRIGAN, R. E. CALDWELL, R. G. LEIGHTY, and F. B. SMITH. Physical, spectrographic and chemical analyses of some virgin Florida soils. U Florida Agric Exp Station Bull No. 524 (1953).

(*4*) GAMMON, N., Jr. The behavior of potassium and potassium fertilizers in Florida soil. Proceedings of Soil and Crop Science Society of Florida (1957) p. 17.

(*5*) General soil map of Florida, Florida Agricultural Experiment Stations (1962).

(*6*) FISKEL, J. G. A., N. GAMMON, Jr., R. E. CALDWELL, and F. B. SMITH. Mineralogical properties of representative Florida soils. Florida Agric Exp Station, Annual Report (1954).

(*7*) FISKEL, J. G. A., and S. B. McCALEB. Nature of the clay fractions of some soils in Florida. Soil Sci 76:431 (1953).

(*8*) LACY, W. J. Decontamination of radioactively contaminated water by slurrying with clay. Indiana Eng Chem 46:1061 (1954).

(*9*) STRAUB, C. P. Low-level radioactive wastes: Their handling, treatment, and disposal. U.S. Atomic Energy Commission, Division of Technical Information, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1964).

(*10*) GOLDSMITH, W. A., and E. J. MIDDLEBROOKS. Decontamination of radioactively contaminated water by slurrying with yasoo and silpha clay. JAWWA, in press.

(*11*) GAMMON, N., Jr. Sodium and potassium requirements of pangola and other pasture grasses. Soil Sci 76:81 (1953).

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake of the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake from the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for assessing the hazards of normal peacetime nuclear operations, assuming continuous exposure of the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium–89, strontium–90, and cesium–137, Report No. 7. Superindent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1965).

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–June 1966	March 1967

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1. Pasteurized Milk Network
April 1967

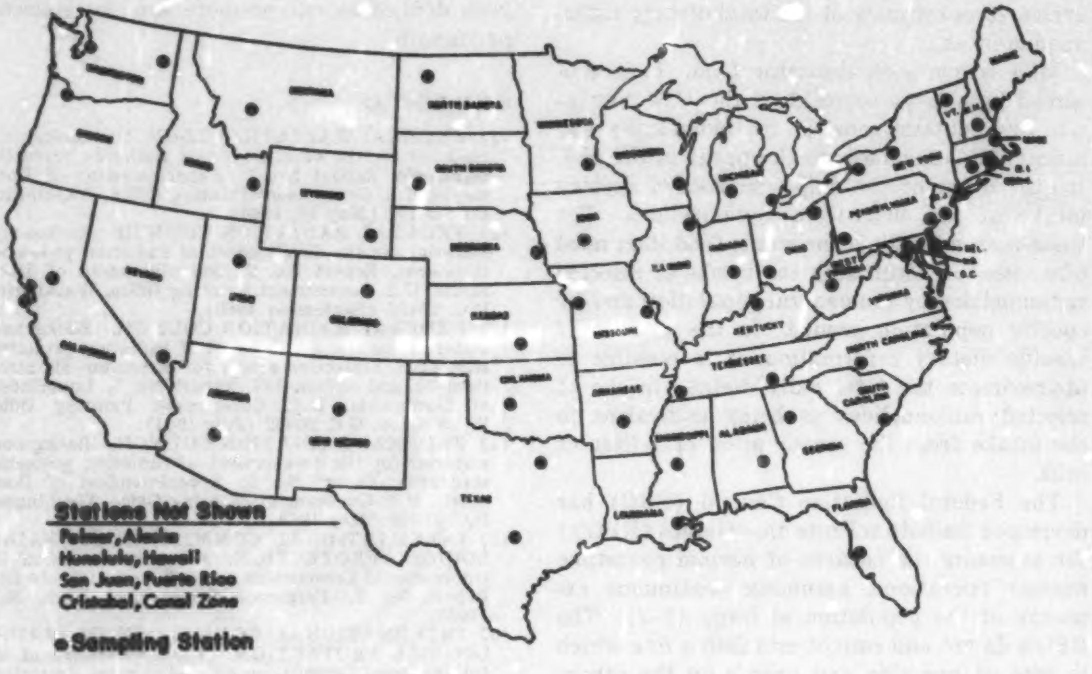
National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN), was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent de-

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Radionuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	Less than 100	10	100 or greater	10
Barium-140	Less than 100	10	100 or greater	10
Cesium-137	Less than 100	10	100 or greater	10
Strontium-89	Less than 50	5	50 or greater	10
Strontium-90	Less than 20	2	20 or greater	10

[a] Two standard deviations.


WASHINGTON
MONTANA
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NEVADA
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UTAH
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OKLAHOMA
NEW MEXICO
TEXAS
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
TENNESSEE
KENTUCKY
NORTH CAROLINA
SOUTH CAROLINA
VIRGINIA
OHIO
INDIANA
ILLINOIS
IOWA
MINNESOTA
WISCONSIN
MICHIGAN
PENNSYLVANIA
NEW YORK
MAINE
VT.
Stations Not Shown
Palmer, Alaska
Honolulu, Hawaii
San Juan, Puerto Rico
Cristobal, Canal Zone
● Sampling Station

Figure 1. Pasteurized Milk Network sampling stations

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Table 2. Average concentration of radionuclides in pasteurized milk for the first quarter 1967 and April 1967[a]

Sampling location		Radionuclide concentration (pCi/liter)							
		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		First quarter 1967	April 1967[b]	First quarter 1967	April 1967	First quarter 1967	April 1967	First quarter 1967	April 1967
Ala:	Montgomery	<5	< 5	12	12	10	0	15	20
Alaska:	Palmer	<5	< 5	9	6	0	0	20	25
Ariz:	Phoenix	<5	< 5	2	7	0	0	< 5	< 5
Ark:	Little Rock	<5	< 5	23	26	0	0	20	20
Calif:	Sacramento	<5	15	3	5	0	0	< 5	10
	San Francisco	<5	10	4	5	0	0	< 5	15
C.Z:	Cristobal	<5	< 5	6	5	0	0	25	35
Colo:	Denver	<5	< 5	6	5	0	0	< 5	5
Conn:	Hartford			10	9	0	0	25	20
Del:	Wilmington			11	11	0	0	20	20
D.C:	Washington	<5	< 5	10	10	0	0	15	20
Fla:	Tampa	<5	< 5	9	9	0	0	70	70
Ga:	Atlanta	<5	< 5	17	17	10	0	25	25
Hawaii:	Honolulu	<5	< 5	5	5	0	0	15	15
Idaho:	Idaho Falls	<5	< 5	7	6	0	0	10	15
Ill:	Chicago	<5	< 5	9	11	0	0	20	20
Ind:	Indianapolis	<5		10	10	0	0	20	15
Iowa:	Des Moines	<5	< 5	9	9	0	0	10	15
Kans:	Wichita	<5	< 5	9	7	0	0	5	10
Ky:	Louisville	<5	< 5	14	15	0	0	15	10
La:	New Orleans	<5	< 5	27	20	0	0	35	20
Maine:	Portland	<5		13	11	0	0	45	20
Md:	Baltimore	<5	< 5	11	12	0	0	20	25
Mass:	Boston	<5	< 5	13	12	0	0	25	20
Mich:	Detroit			10	9	0	0	20	20
	Grand Rapids	<5		11	12	0	0	25	25
Minn:	Minneapolis	<5	< 5	14	15	0	0	15	20
Miss:	Jackson	<5	< 5	21	25	10	0	20	20
Mo:	Kansas City	<5	5	10	9	0	0	5	10
	St. Louis	<5	5	11	10	0	0	10	15
Mont:	Helena	<5	< 5	7	6	0	0	10	10
Nebr:	Omaha	<5	< 5	10	7	0	0	10	20
Nev:	Las Vegas	<5	< 5	3	2	0	0	< 5	< 5
N.H:	Manchester	<5		16	13	0	0	45	30
N.J:	Trenton	<5		10	10	0	0	25	25
N. Mex:	Albuquerque	<5	< 5	5	4	0	0	< 5	< 5
N.Y:	Buffalo	<5		9	9	0	0	20	20
	New York City	<5		11	11	0	0	20	20
	Syracuse	<5		9	8	0	0	20	20
N.C:	Charlotte	<5	< 5	18	21	0	0	20	20
N. Dak:	Minot	<5	5	17	18	0	0	15	25
Ohio:	Cincinnati	<5		11	11	0	0	20	15
	Cleveland	<5		12	10	0	0	20	20
Okla:	Oklahoma City	<5	< 5	10	11	0	0	10	15
Ore:	Portland	5	10	8	11	0	0	10	25
[illegible]	Philadelphia	<5		11	10	0	0	20	15
	Pittsburgh			13	14	0	0	25	25
[illegible]	San Juan	<5	< 5	5	4	0	0	15	15
[illegible]	[illegible]idence	<5		11	11	0	0	30	25
[illegible]	[illegible]ton	<5	< 5	18	18	20	0	30	30
[illegible]	[illegible] City	<5	5	11	11	0	0	15	20
[illegible]	[illegible]ooga	<5	< 5	16	18	0	0	20	20
	[illegible]is	<5	< 5	13	15	0	0	10	10
[illegible]	[illegible]	<5	< 5	4	4	20	0	10	5
	[illegible]	<5	< 5	9	11	10	0	10	15
[illegible]	[illegible]ake City	<5	< 5	7	6	0	0	10	15
[illegible]	[illegible]gton	<5		11	11	0	0	25	25
[illegible]	[illegible]olk	<5	< 5	12	14	0	0	15	15
[illegible]	[illegible]ttle	<5	5	11	11	0	0	25	30
	[illegible]ane	<5	< 5	11	10	0	0	20	25
[illegible]	Charleston	<5	< 5	12	12	0	0	15	10
Wisc:	Milwaukee			8	7	0	0	20	20
Wyo:	Laramie	<5	< 5	7	4	0	0	10	5
Network average		<5	< 5	11	11	0	0	20	20

[a] Barium-140 concentrations for all stations were below the limits of detectability.

[b] Blank indicates that no strontium-89 determinations were made on samples during month.

Note: On April 10, 1967, Southwestern Radiological Health Laboratory began analyzing for strontium-90 by the rapid ion exchange method replacing the routine ion exchange method previously used.

scription of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (1).

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The results for the first quarter of 1967 and April 1967 are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable values; however, for iodine-131 and barium-140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium-90 and cesium-137 are presented in tables 3 and 4 for April 1966 and November 1966 through April 1967. The average strontium-90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution, strontium-90 concentrations in milk at PMN stations, April 1966 and November 1966–April 1967

Strontium-90 (pCi/liter)	Number of stations						
	1966			1967			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 10	8	19	23	24	21	25	25
10–19	50	40	35	36	38	35	34
20–29	3	4	5	3	4	2	4
30–39	2	0	0	0	0	1	0

Table 4. Frequency distribution of monthly average cesium-137 concentrations in milk at PMN stations, April 1966 and November 1966–April 1967

Cesium-137 (pCi/liter)	Number of stations						
	1966			1967			
	Apr	Nov	Dec	Jan	Feb	Mar	Apr
Under 50	55	61	62	62	62	62	62
50–99	7	2	1	1	1	1	1
100–149	1	0	0	0	0	0	0

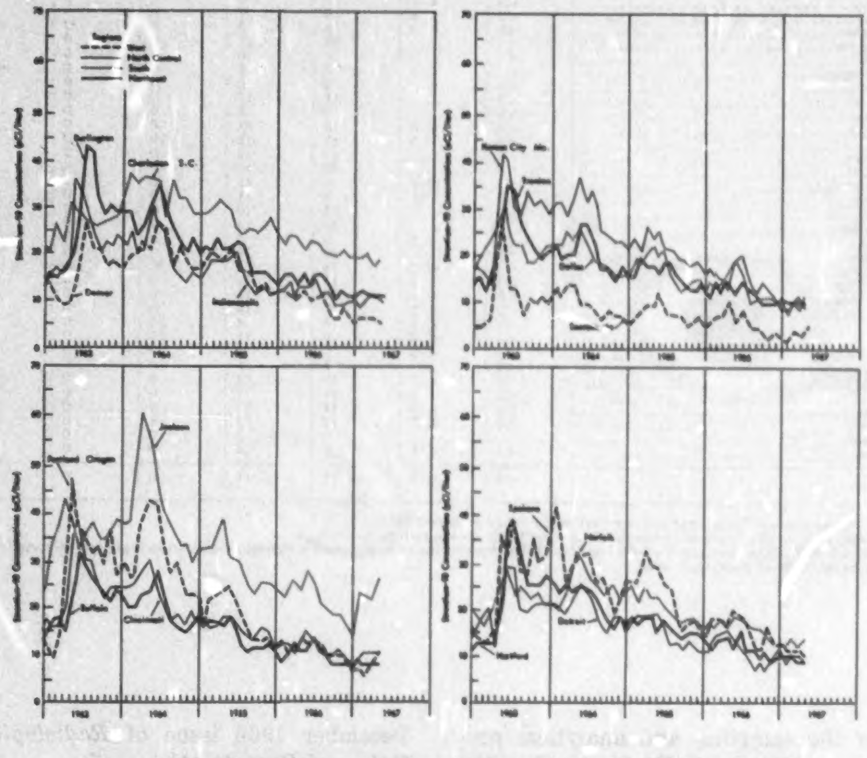

Figure 2. Strontium-90 concentrations in pasteurized milk, 1961–April 1967

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2. Canadian Milk Network April 1967[1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine-131, and monthly composites are analyzed for strontium-90, cesium-137, and stable calicum and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (*2*).

The April 1967 monthly average strontium-90, cesium-137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine-131 and strontium-89 concentrations were below minimum detectable levels.

Table 5. Stable elements and radionuclides in Canadian whole milk, April 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.13	1.4	13	34
Edmonton	1.12	1.5	13	40
Ft. William	1.13	1.5	16	44
Fredericton	1.09	1.5	19	46
Halifax	1.15	1.5	17	43
Montreal	1.10	1.5	10	37
Ottawa	1.17	1.6	9	23
Quebec	1.08	1.6	18	49
Regina	1.12	1.5	12	27
St. John's, Nfld	1.10	1.5	16	51
Saskatoon	1.14	1.4	12	27
Sault Ste. Marie	1.12	1.5	18	38
Toronto	1.16	1.5	7	18
Vancouver	1.14	1.5	19	68
Windsor	1.12	1.5	8	21
Winnipeg	1.09	1.6	10	48
Average	1.12	1.5	13.5	38

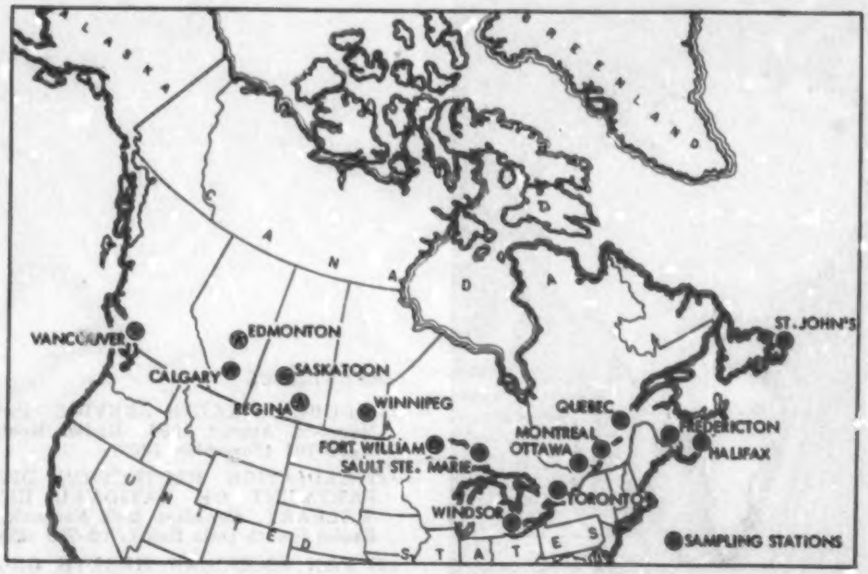

Figure 3. Canadian milk sampling stations

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[1] Prepared from May 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Milk Sampling Program April 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

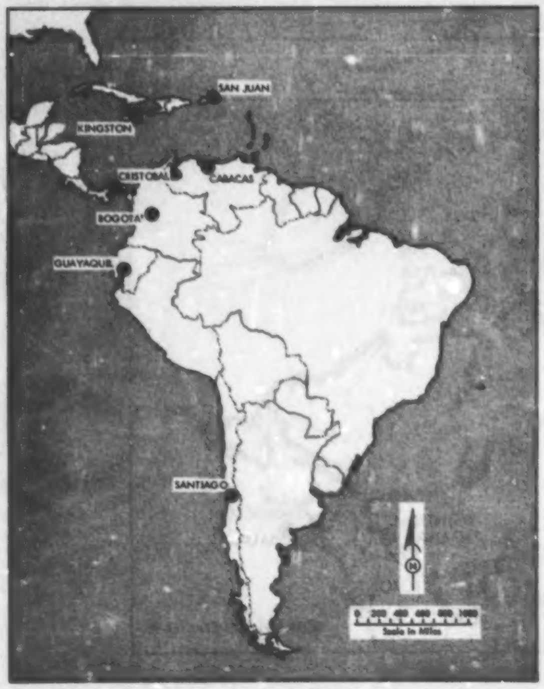


Figure 4. Pan American Milk Sampling Program stations

Table 6 presents stable potassium, strontium-90, and cesium-137 monthly average concentrations for April 1967.

Table 6. Stable element and radionuclide concentration in PAHO milk, April 1967[a]

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile:				
Santiago	4	1.4	4	14
Colombia:				
Bogota	1	1.4	2	< 5
Ecuador:				
Guayaquil	1	1.5	2	< 5
Jamaica:				
Kingston	1	1.5	6	100
Mandeville	NS			
Montego Bay	NS			
Venezuela:				
Caracas	NS			
Canal Zone:				
Cristobal[b]	4	--------	5	35
Puerto Rico:				
San Juan[b]	4	--------	4	15

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples. Strontium-89 was less than 5 pCi/liter for all samples.

[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, from the Pasteurized Milk Network are presented.

NS, no sample collected.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7:698–701 (December 1966).

(*2*) RADIATION PROTECTION DIVISION, DEPARTMENT OF NATIONAL HEALTH AND WELFARE. Canadian Milk Network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704–705 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows these States which report milk surveillance actiivties in *Radiological Health Data and Reports*. States having programs appearing in the current issue are highlighted in the figure. A summary of other State programs previously covered, the reporting period, and issue of appearance are as follows.

State milk network	Period covered	Last presented
California	October–December 1966	June 1967
Colorado	January–March 1967	July 1967
Florida	April–June 1966	October 1966
Oklahoma	January–March 1967	July 1967
Oregon	October–December 1966	June 1967
Tennessee	January–March 1967	July 1967
Texas	January–March 1967	July 1967
Washington	October–December 1966	June 1967

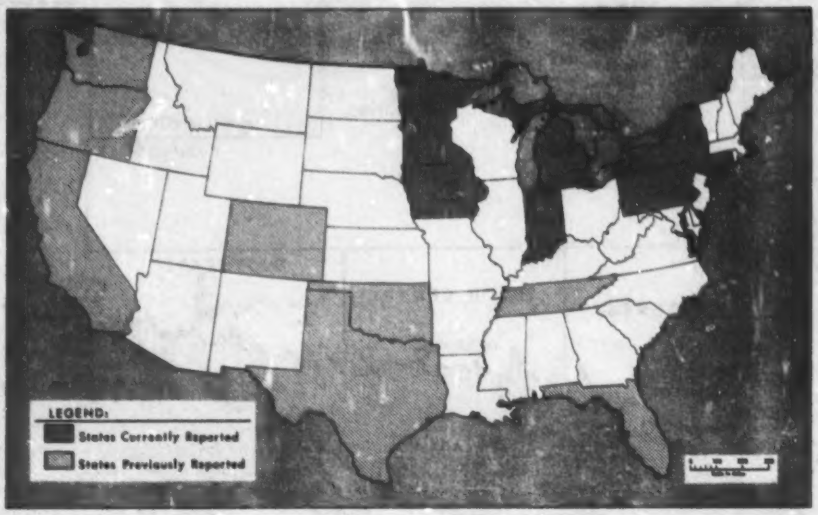


Figure 1. State milk programs reported

1. Connecticut Milk Network
January–March 1967

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-ray emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 2). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma-ray emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma-ray emitters are determined by gamma-ray spectroscopy.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in central Connecticut pasteurized milk are presented in table 1. These results are presented graphically in figure 3.

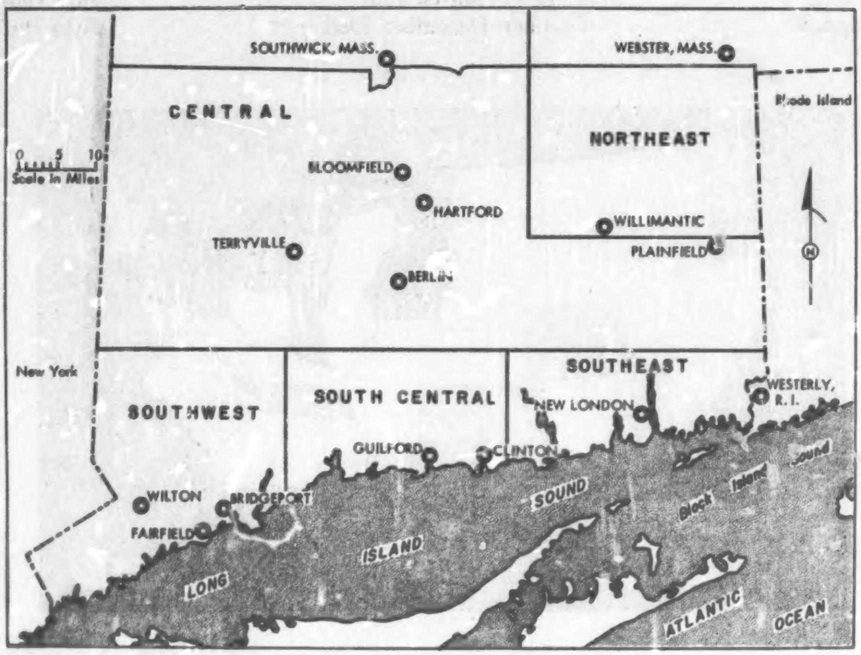
Table 1. Radionuclide concentrations in central Connecticut pasteurized milk, January–March 1967

Month 1967	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
January	ND	9	<10	20
February	ND	9	<10	20
March	ND	9	<10	20

ND, below detectable levels.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967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WEBSTER, MASS.
CENTRAL
Rhode Island
NORTHEAST
0 5 10
Scale in Miles
BLOOMFIELD
HARTFORD
WILLIMANTIC
PLAINFIELD
TERRYVILLE
BERLIN
N
New York
SOUTHEAST
SOUTH CENTRAL
SOUTHWEST
WESTERLY, R.I.
NEW LONDON
GUILFORD
CLINTON
WILTON
BRIDGEPORT
FAIRFIELD
SOUND
Block Island Sound
ISLAND
LONG
ATLANTIC OCEAN

Figure 2. Connecticut pasteurized milk sampling areas

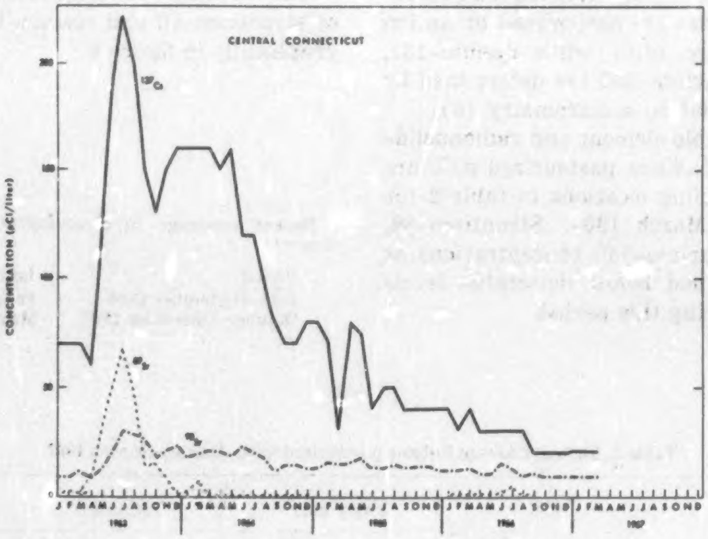

Figure 3. Radionuclide concentrations in central Connecticut pasteurized milk, 1963–March 1967

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2. Indiana Milk Network
January–March 1967

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds: northeast, northwest, central, southeast, and southwest (figure 4). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium–89 and strontium–90. Cesium–137, iodine–131, and barium–140 are determined weekly for at least two of the milksheds. When iodine–131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.

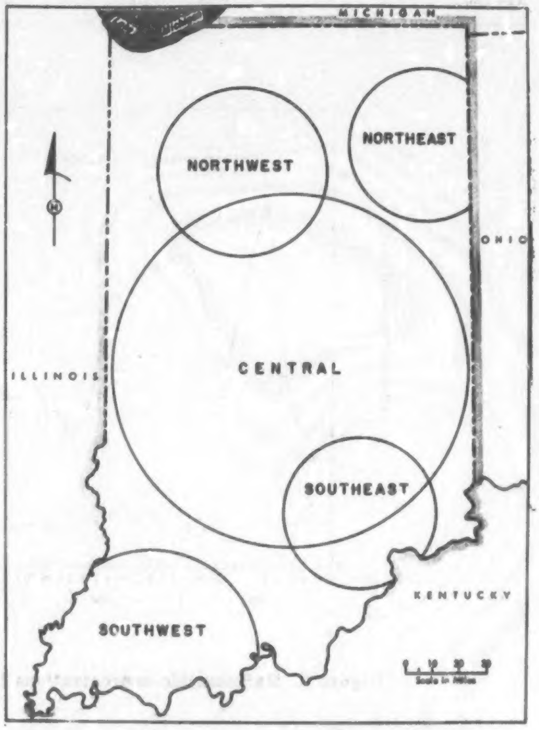

Figure 4. Indiana pasteurized milk sampling areas

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Strontium-89 and strontium-90 concentrations in milk samples are determined by an ion exchange procedure (*1,2*) while cesium-137, iodine-131, and barium-140 are determined by gamma-ray scintillation spectrometry (*3*).

The monthly stable element and radionuclide concentrations in Indiana pasteurized milk are presented by sampling locations in table 2 for January through March 1967. Strontium-89, iodine-131, and barium-140 concentrations at all stations remained below detectable levels of 10 pCi/liter during this period.

The monthly network average concentrations of strontium-90 and cesium-137 are presented graphically in figure 5.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

Table 2. Radionuclides in Indiana pasteurized milk, January–March 1967

Sampling location	Calcium (g/liter)			Potassium-40 (pCi/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Northeast	1.17	1.16	1.16	1,300	1,290	1,260	9	10	10	15	15	15
Southeast	1.25	1.16	1.17	1,320	1,330	1,320	15	14	13	15	15	15
Central	1.25	1.14	1.16	1,340	1,350	1,340	10	10	10	10	15	10
Southwest	1.23	1.14	1.14	1,280	1,350	1,220	13	12	15	15	15	20
Northwest	1.21	1.18	1.18	1,330	1,380	1,370	13	11	14	15	20	15
Average	1.22	1.16	1.16	1,310	1,340	1,300	12	11	12	15	15	15

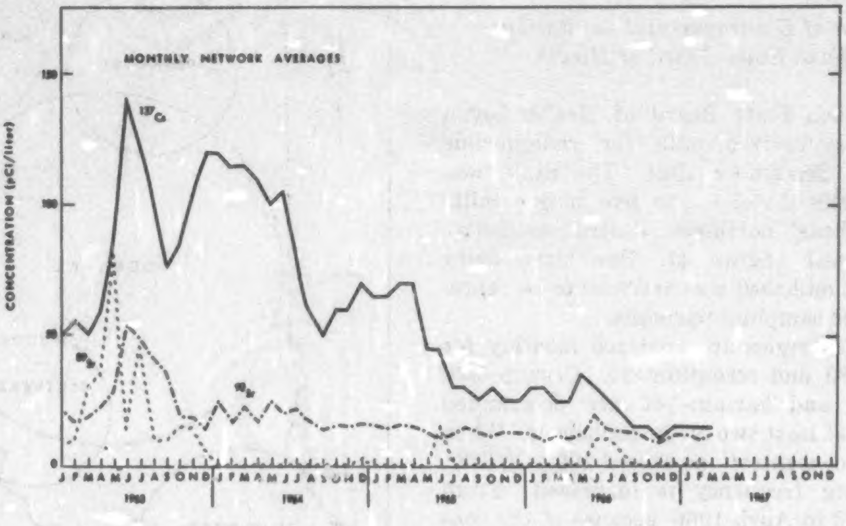

Figure 5. Radionuclide concentrations in Indiana pasteurized milk, 1963–March 1967

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3. Iowa Milk Network
January 1965–March 1967

State Hygienic Laboratory and the
Iowa State Department of Health

In Iowa, radiological health activities are conducted jointly by the State Department of Health and the State Hygienic Laboratory, with the State Hygienic Laboratory performing the surveillance and analytical functions.

In August 1962 the State Hygenic Laboratory of Iowa began sampling milk for iodine-131. In May 1964 this routine surveillance was expanded to include cesium-137 and strontium-90.

One-gallon samples are collected from 4 stations, selected to give a broad coverage of milk production areas in the State (figure 6). Producers furnishing to the Spencer bottling area are quite restricted to that northwest part of the State and the majority of milk bottled in Iowa City comes from six counties in east central Iowa. The Des Moines shed comprises approximately 60 counties covering about two thirds of the State radiating out of Des Moines in all directions. The Charles City bottling area covers primarily north central Iowa. At present, the Iowa City and Des Moines stations are sampled weekly and the Spencer and Charles City stations are sampled monthly. This sampling frequency is increased when nuclide concentrations warrant closer surveillance. The samples are forwarded to the State Hygienic Laboratory at the University of Iowa, Iowa City for analysis.

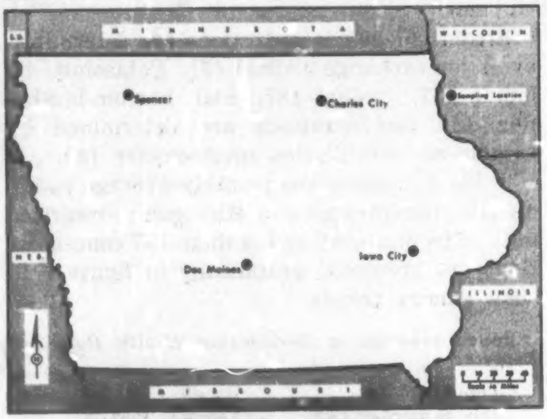

Figure 6. Iowa milk sampling locations

Analytical procedures

Iodine-131 and cesium-137 together with barium-lanthanum-140 and potassium-40 are determined by gamma-scintillation spectrometry using a 4- by 4-inch NaI (Tl) crystal and 512-channel pulse height analyzer. All samples are 3.5 liters and are counted for 80 minutes in Marinelli beakers with ther results being calculated using a 4 by 4 matrix. Strontium-90 is determined by an ion exchange system described by Porter *et al* (*1*). One liter of milk is passed through an ion exchange column; yttrium-90 is eluted from the resin and counted as yttrium oxalate in an automatic low-background proportional counter. Minimum detectable limits are 10 pCi/liter for iodine-131 and cesium-137, and 2 pCi/liter for strontium-90.

Results

Table 3 gives the monthly averages at each of the four locations for January 1965–March 1967, and figure 7 shows graphically the overall network average monthly results for the same period. During this period it can be seen that the concentration levels of cesium-137 and strontium-90 showed a trend to lower values. Iodine-131 was present in any significant amount only during the month of June 1965.

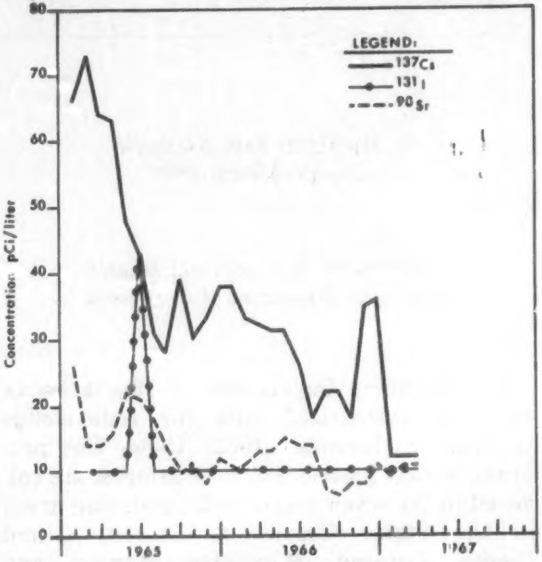

Figure 7. Radionuclide concentrations in Iowa milk
January 1965–March 1967

Table 3. Radionuclide concentrations in Iowa milk, January 1965–March 1967

Sampling date	Radionuclide concentration (pCi/liter)											
	Iowa City			Des Moines			Spencer			Charles City		
	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137	Strontium-90	Iodine-131	Cesium-137
1965												
January	22	<10	60	22	<10	71	31	<10	62	20	<10	72
February	19	<10	69	17	<10	78	10	<10	60	12	<10	65
March	14	<10	71	15	<10	72	14	<10	60	13	<10	53
April	20	<10	61	23	<10	62	17	<10	65	23	<10	62
May	25	11	44	21	<10	47	21	<10	47	20	<10	52
June	25	37	38	27	30	45	14	33	41	19	70	49
July	20	<10	29	17	<10	31	16	<10	25	NA	<10	40
August	9	<10	27	14	<10	32	8	<10	23	20	<10	31
September	13	<10	30	11	<10	40	7	<10	38	10	<10	38
October	10	<10	29	10	<10	29	10	<10	29	13	<10	34
November	12	<10	29	9	<10	31	10	<10	36	NA	<10	35
December	13	<10	38	16	<10	46	7	<10	33	NA	<10	36
1966												
January	9	<10	38	18	<10	42	13	<10	45	NA	<10	29
February	11	<10	31	14	<10	37	7	<10	30	NA	NA	NA
March	15	<10	32	19	<10	35	6	<10	29	NA	NA	NA
April	13	<10	20	13	<10	28	13	<10	36	NA	NA	NA
May	26	<10	31	14	<10	38	4	<10	25	NA	NA	NA
June	13	<10	23	15	<10	28	NA	<10	27	NA	NA	NA
July	9	<10	18	10	<10	18	NA	<10	NA	NA	NA	NA
August	5	<10	23	9	<10	20	NA	<10	22	NA	NA	NA
September	5	<10	13	7	<10	21	NA	<10	33	NA	NA	NA
October	6	<10	13	8	<10	21	9	<10	19	NA	NA	NA
November	9	<10	20	7	<10	35	8	<10	34	4	<10	44
December	8	<10	24	6	<10	29	6	<10	33	24	<10	48
1967												
January	11	<10	16	10	12	16	6	<10	10	10	<10	15
February	12	<10	12	8	<10	15	10	<10	12	10	<10	10
March	10	<10	10	10	<10	18	11	<10	10	10	<10	10

NA, no analysis.

4. Michigan Milk Network
January–March 1967

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 8). Milkshed samples are composited from dairies in proportion to sales volumes.

Strontium-90 concentrations are determined by an ion exchange method (*5*). Potassium-40, iodine-131, cesium-137, and barium-lanthanum-140 concentrations are determined by gamma-ray scintillation spectrometry (*5*).

Table 4 presents the monthly average radionuclide concentrations in Michigan pasteurized milk. Strontium-90 and cesium-137 concentrations are presented graphically in figure 9 to show general trends.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

8b

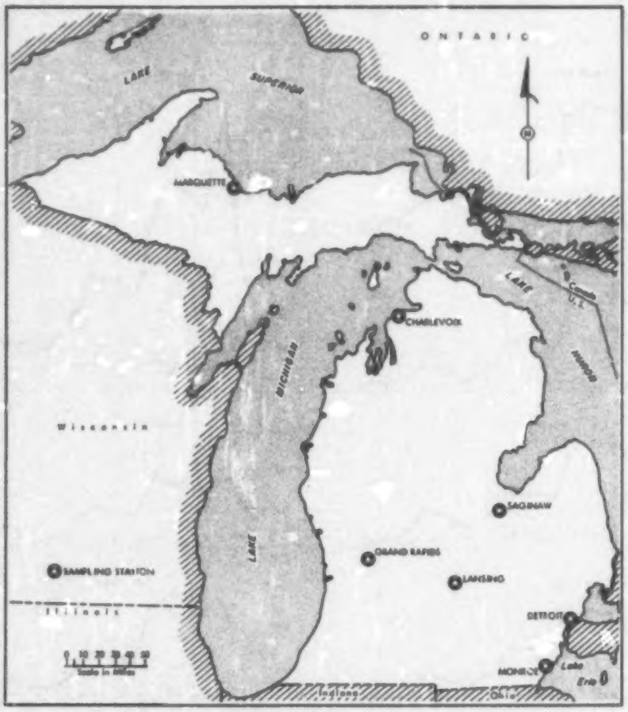
ONTARIO
LAKE
SUPERIOR
N
MARQUETTE
LAKE
HURON
Canada
U.S.
CHARLEVOIX
LAKE
MICHIGAN
Wisconsin
SAGINAW
GRAND RAPIDS
SAMPLING STATION
LANSING
Illinois
DETROIT
0 10 20 30 40 50
Scale in Miles
MONROE
Lake
Erie
Indiana
Ohio

Figure 8. Michigan pasteurized milk network sampling locations

Table 4. Radionuclide concentration in Michigan pasteurized milk, January–March 1967

Sampling location	Month	Radionuclide concentration (pCi/liter)			
		Potassium-40	Strontium-90	Iodine-131	Cesium-137
Charlevoix	January	1,350	7	<14	19
	February	1,310	8	<14	17
	March	1,370	7	<14	17
Detroit	January	1,340	6	<14	14
	February	1,340	6	<14	11
	March	1,350	6	<14	15
Grand Rapids	January	1,330	7	<14	14
	February	1,360	7	<14	18
	March	1,350	6	<14	16
Lansing	January	1,340	6	<14	12
	February	1,340	6	<14	16
	March	1,350	5	<14	14
Marquette	January	NA	NA	NA	NA
	February	NA	NA	NA	NA
	March	1,430	10	<14	37
Monroe	January	1,330	5	<14	9
	February	1,300	4	<14	10
	March	1,320	4	<14	8
Saginaw	January	1,370	6	<14	14
	February	1,320	5	<14	16
	March	1,380	5	<14	13
Average	January	1,340	6	<14	14
	February	1,330	6	<14	15
	March	1,360	6	<14	17

NA, no analysis.

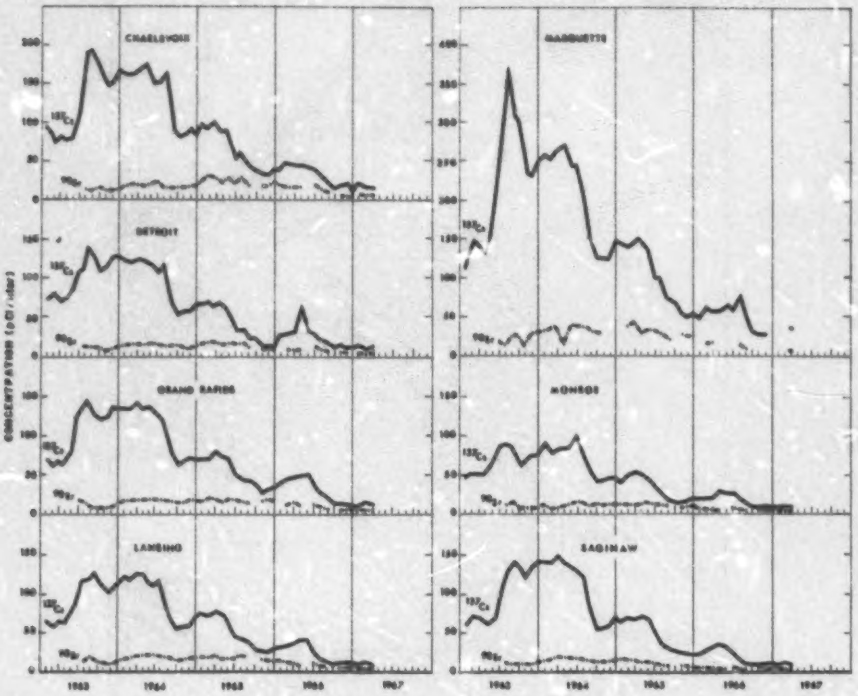

Figure 9. Radionuclide concentrations in Michigan pasteurized milk, 1963–March 1967

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5. Minnesota Milk Network
January–March 1967

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium-90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 10) and analyzed for strontium-90, iodine-131, and cesium-137. One-liter samples of processed Grade A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health Department district offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned.

Strontium-90 concentrations are determined radiochemically, while iodine-131 and cesium-137 concentrations are determined by gamma-ray spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (*6*).

Strontium-90 and cesium-137 concentrations in milk are given for January through March 1967 in table 5, and are presented graphically by milkshed in figure 11 for the period 1961 through March 1967. Iodine-131 concentrations for January through March 1967 were less than 10 pCi/liter in all 24 samples.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

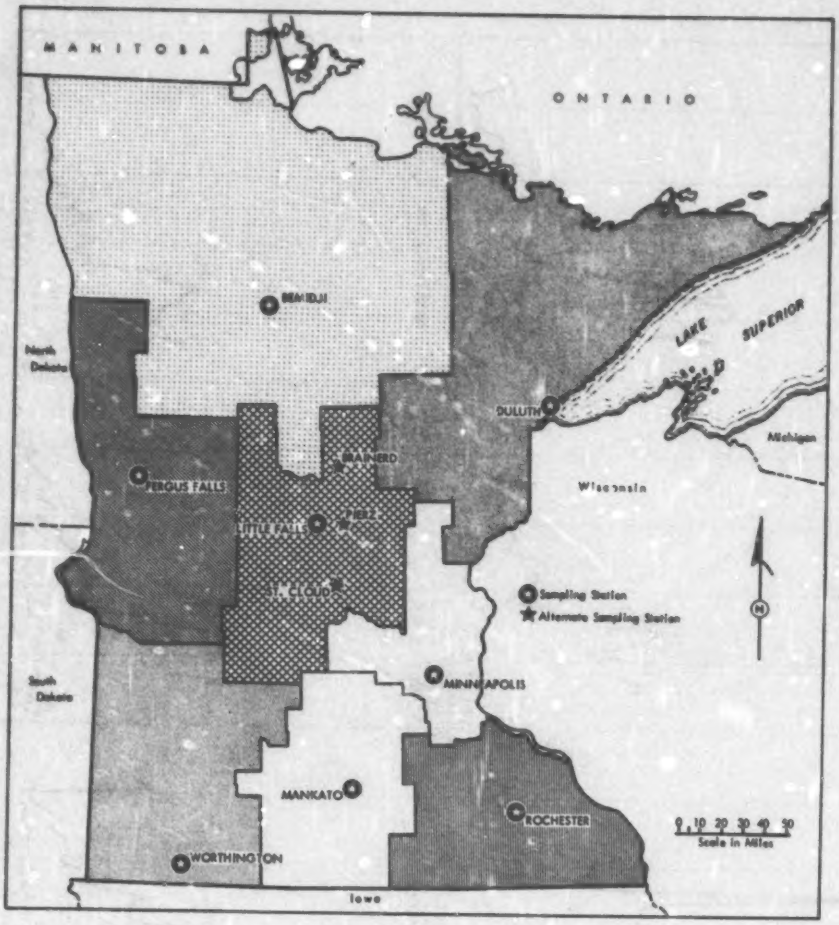
MANITOBA
ONTARIO
LAKE SUPERIOR
North Dakota
South Dakota
Iowa
Wisconsin
Michigan
BEMIDJI
DULUTH
BRAINERD
FERGUS FALLS
LITTLE FALLS
PIERZ
ST. CLOUD
MINNEAPOLIS
MANKATO
ROCHESTER
WORTHINGTON
Sampling Station
Alternate Sampling Station
N
0 10 20 30 40 50
Scale in Miles

Figure 10. Minnesota milk sampling locations

Table 5. Radionuclide concentrations in Minnesota pasteurized milk, January–March 1967

Sampling location	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	January	February	March	January	February	March
Bemidji	21	19	20	16	28	39
Mankato	8	9	8	18	21	12
Rochester	9	11	11	17	11	20
Duluth	21	23	24	46	64	47
Worthington	9	10	9	19	9	14
Minneapolis	14	15	15	23	15	42
Fergus Falls	10	11	10	18	9	20
Little Falls	14	13	13	28	14	24
Average	13	14	14	23	21	27

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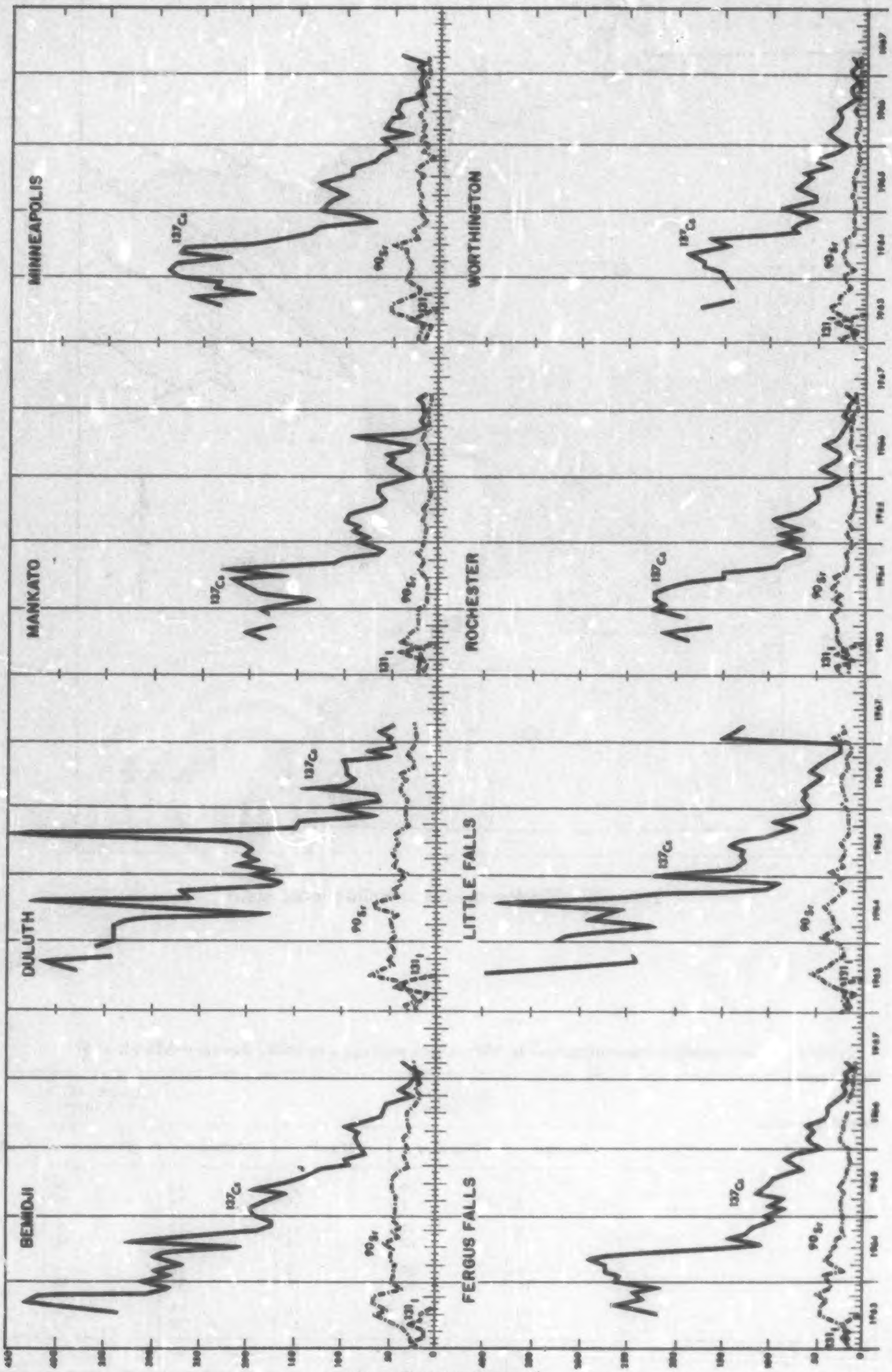

Figure 11. Radionuclide concentrations in Minnesota milk, 1963–March 1967

6. New York Milk Network
January–March 1967

Division of General Engineering and Radiological Health
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 12) are analyzed for strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 by the New York State Department of Health. At Buffalo and Newburgh, milk samples are collected daily from processing plants and composited weekly for radiochemical analyses. At Messena, and Syracuse daily samples are composited over a two week period and then analyzed. In New York City, a milk sample representing the total milk supply for 1 day is analyzed weekly. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-ray emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-ray emitting radionuclides in milk are determined by scintillation spectrometry. Radioiodine is selectively removed in an anion exchange resin and the resin is analyzed for iodine–131 (*7, 8*). The resin effluent is analyzed and the resulting spectral data is resolved by the application of a matrix method of analysis (*9*).

The analytical procedure for determining strontium–89 and strontium–90 concentrations employs an ion exchange system similar to that developed by Porter and Kahn (*9*).

The monthly average radionuclide concentrations for strontium–89, strontium–90, iodine–131, and cesium–137 are shown in table 6 for the period January through March 1967. During this period, essentially all iodine-131 and strontium–89 concentrations were below their minimum dectable levels of 5 pCi/liter and 3 pCi/liter, respectively. Cesium–137 and iodine–131 concentrations since 1963 are presented graphically in figure 13.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

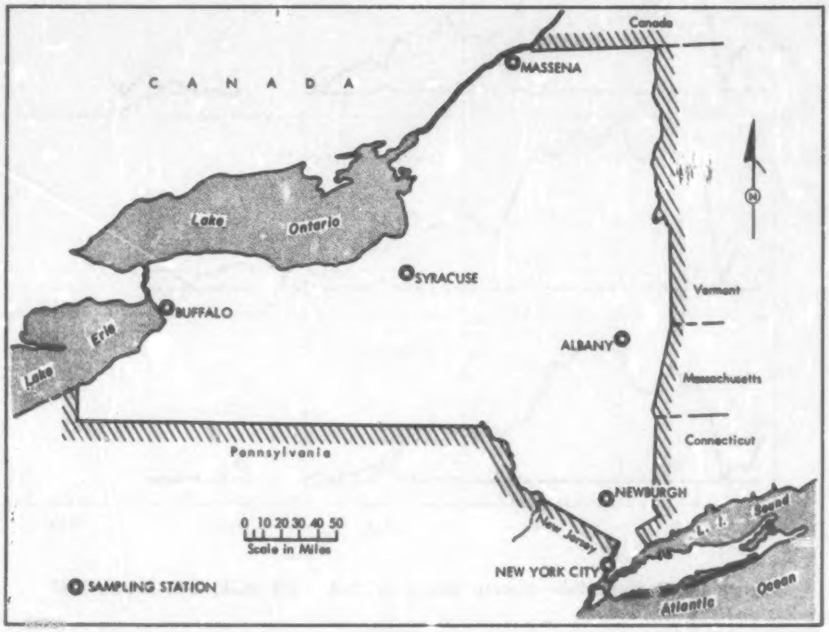

Figure 12. New York milk sampling locations

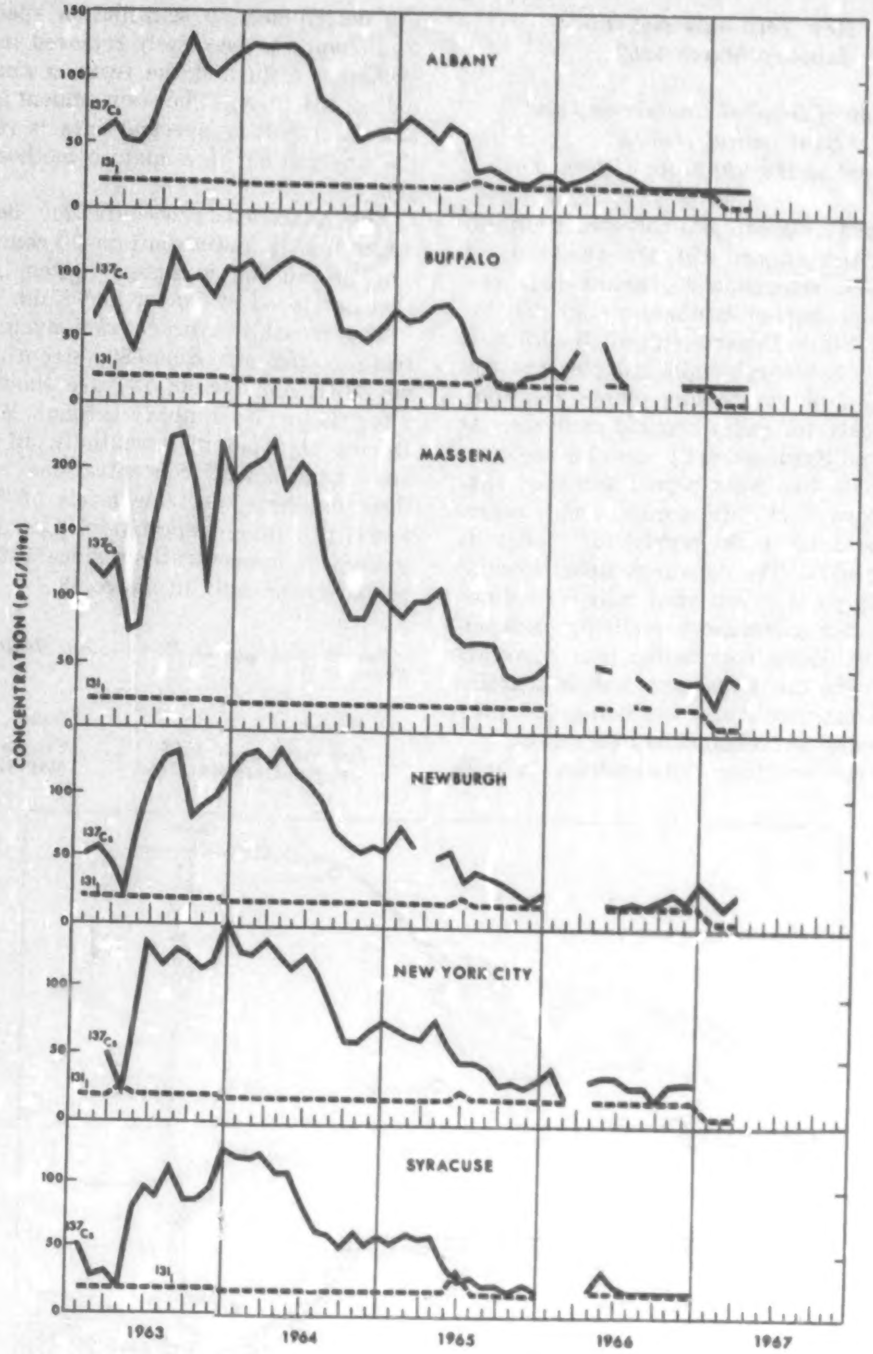

Figure 13. Radionuclide concentrations in New York milk, 1963–March 1967

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Table 6. Radionuclide concentrations in New York pasteurized milk, January-March 1967

Sampling location	Month	Radionuclide concentrations (pCi/liter)			
		Strontium-89	Strontium-90	Iodine-131	Cesium-137
Albany	January	ND	6	ND	ND
	February	ND	7	ND	ND
	March	ND	5	ND	ND
Buffalo	January	ND	5	ND	ND
	February	ND	5	ND	ND
	March	ND	4	ND	ND
Massena	January	ND	8	ND	31
	February	ND	11	ND	48
	March	4	3	ND	43
Newburgh	January	ND	7	ND	26
	February	ND	8	ND	ND
	March	ND	9	ND	30
New York	January	ND	6	ND	ND
	February	ND	7	ND	ND
	March	ND	10	ND	ND
Syracuse	January	NR	NR	NR	NR
	February	NR	NR	NR	NR
	March	NR	NR	NR	NR

ND, not detectable. Detectable limits are: iodine-131, 5 pCi/liter; strontium-89, 3 pCi/liter; strontium-90, 3 pCi/liter; and cesium-137, 20 pCi/liter.

NR, not reported.

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7. Pennsylvania Milk Network
January–March 1967

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 14). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location subsamples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the weekly samples are combined for monthly analyses. Strontium-90 analyses have been carried out since April 1963.

7

The monthly average potassium-40, strontium-90, iodine-131, and cesium-137 concentrations in pasteurized milk are given in table 7. For comparative purposes, strontium-90, iodine-131, and cesium-137 network average concentrations are presented graphically in figure 15.

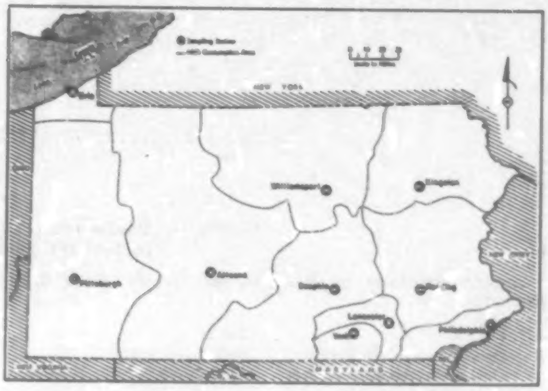

Figure 14. Pennsylvania pasteurized milk network sampling locations

The chemical separation technique for strontium-90 is essentially an ion exchange method described by Porter *et al* (*1*).

Table 7. Radionuclide concentrations in Pennsylvania pasteurized milk, January–March 1967

Sampling location	Radionuclide concentration (pCi/liter)											
	Potassium-40			Strontium-90			Iodine-131			Cesium-137		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Altoona	860	835	910	15	13	11	<10	<10	<10	17	19	15
Dauphin	820	865	865	10	12	13	<10	<10	<10	14	19	22
Erie	855	940	910	15	12	15	<10	<10	<10	15	18	24
Kingston	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lancaster	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Philadelphia	850	890	875	11	13	9	13	<10	<10	12	19	18
Pittsburgh	820	880	880	14	14	12	12	<10	<10	15	17	19
Reading	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Williamsport	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
York	900	865	890	7	8	9	<10	<10	<10	9	12	17
Average	855	875	885	12	12	12	11	<10	<10	14	17	19

NS, no sample.

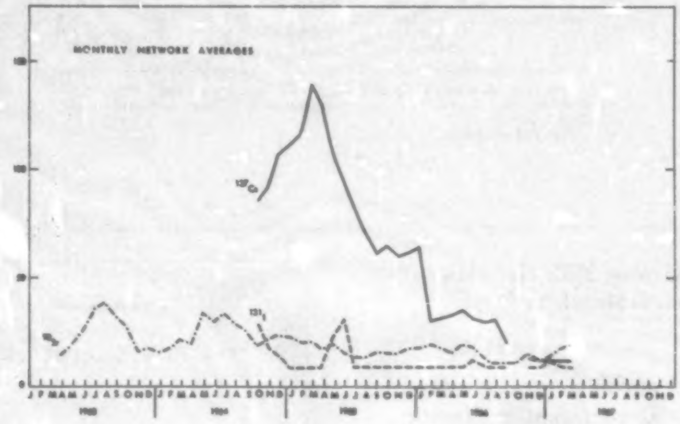

Figure 15. Radionuclide concentrations in Pennsylvania pasteurized milk, 1963–March 1967

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	February 1967
October–December 1966	May 1967

REFERENCES

(1) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determinations of strontium-90 in milk by an ion exchange method. Anal Chem 33:1306–1308 (September 1961).

(2) PORTER, C., and B. KAHN. Improved determinations of strontium-90 in milk by an ion-exchange method. Anal Chem 36:676–678 (March 1964).

(3) INDIANA STATE BOARD OF HEALTH, BUREAU OF ENVIRONMENTAL SANITATION. Indiana milk network, April–June 1965. Radiol Health Data 6:612–614 (November 1965).

(4) PORTER, C., R. AUGUSTINE, J. MATUSEK, Jr., and M. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples. PHS No. 999–RH–10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

(5) MICHIGAN DEPARTMENT OF HEALTH. Michigan milk network, November 1962–December 1964. Radiol Health Data 6:487–492 (September 1965).

(6) MINNESOTA DEPARTMENT OF HEALTH AND RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January–June 1965. COO–615–17 (August 1965).

(7) JOHNSON, R. H. and T. C. REAVEY. Evaluation of ion exchange cartridges for field sampling of iodine–131 in milk. Nature 208:750–752 (November 20, 1965).

(8) PORTER, C. R. and M. W. CARTER. Field method for rapid collection of iodine–131 from milk. Public Health Rep 80:453–456 (May 1965).

(9) KAHN, B., G. K. MURPHY, C. PORTER, G. R. HAGEE, G. J. KARCHES, and A. S. GOLDIN. Rapid methods for estimating fission product concentrations in milk, PHS Publication No. 999–R–2 (March 1963). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Food and Diet Surveillance Activities

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Results most recently reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Last presented
California Diet	May–August 1966	May 1967
Connecticut Standard Diet	July–December 1966	May 1967
Institutional Diet, PHS	October–December 1966	July 1967
Teenage Diet, FDA	February–November 1965	August 1966
Tri-City Diet, HASL	May–July 1966	June 1967
United Kingdom Diet	Annual summary 1965	December 1966

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SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 at 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes remain within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analyses indicate that the concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Activity	Period reported	Last presented
California Water Sampling Program	January–June 1966	June 1967
Coast Guard Water Sampling Program	1965	November 1966
Minnesota Surface Water Sampling Program	January–June 1966	January 1967
New York Surface Water Sampling Program	June–December 1965	June 1966
Radiostrontium in Tap Water, HASL	March–November 1966	June 1967
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity, February 1967, and Strontium-90, October 1965-June 1966, in Surface Waters of the United States

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of Interior

The monitoring of radioactivity in surface waters of the United States was begun in 1957 as a part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

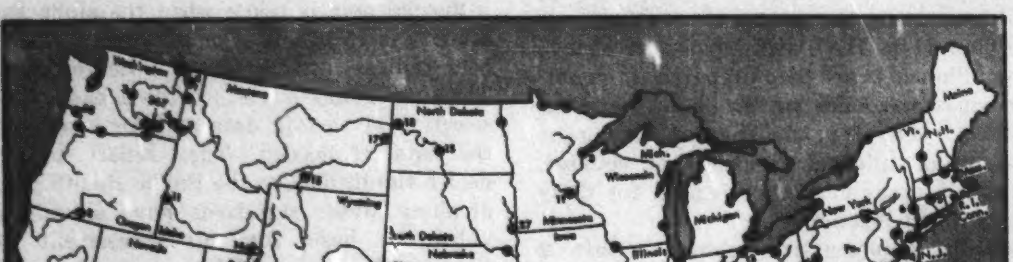
Washington
Montana
North Dakota
Minnesota
Wisconsin
Mich.
Maine
Vt.
N.H.
New York
Michigan
Wyoming
Oregon
Idaho
Nevada
South Dakota
Nebraska
Iowa
Illinois
Ohio
Pa.
N.J.
Indiana
Colorado
Kansas
W.Va.
Virginia
Kentucky
Utah
California
Arizona
Oklahoma
Missouri
Arkansas
N. Carolina
S. Carolina
Texas
New Mexico
Alabama
Georgia
Miss.
La.
Florida

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, February 1967

Sampling procedures

The participating agencies collect 1-liter "grab" samples each week and ship them to the Surveillance System Laboratory in Cincinnati. Presently, gross alpha and beta radioactivity determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta radioactivity determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations during the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8 are used for daily checking of the instrument.

Normally, samples are counted within 2 weeks following collection or within 1 week after compositing. The decay of radioactivity is followed on each sample which shows unusually high radioactivity. Also, if a recount indicates that the original analysis was questionable, values based on the recount are recorded.

Results

Table 1 presents the current preliminary results of the alpha- and beta-particle analysis of U.S. surface waters. The stations on a river are arranged in the table according to their distance from the headwaters. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as < 1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations shown in figure 1, which give the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station.

It has been observed that in water the natural environmental beta radioactivity is usually several times that of the natural environmental alpha radioactivity. Nuclear installations may contribute additional alpha or beta radioactivity whereas fallout contributes primarily additional beta radioactivity. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*9*).

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment (*10*). Changes from these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both January and February, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved solids:

North Platte River, Henry, Neb., and
South Platte River, Julesburg, Colo.

During February, at Morgan City, La., on

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Table 1. Radioactivity in raw surface waters, February 1967

Station	Average beta radioactivity (pCi/liter)			Average alpha radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsburgh, Pa.	–	–	–	–	–	–
Animas River:						
Cedar Hill, N. Mex.	7	9	16	1	2	3
Arkansas River:						
Ponca City, Okla.	4	45	49	1	10	11
Atchafalaya River:						
Morgan City, La.	29	8	37	8	2	10
Bear River:						
Preston, Idaho	0	14	14	0	1	1
Big Horn River:						
Hardin, Mont.	2	13	15	1	7	8
Big Sioux River:						
Sioux Falls, S. Dak.	4	23	27	<1	2	2
Clearwater River:						
Lewiston, Idaho	1	2	3	0	0	0
Clinch River:						
Clinton, Tenn.	1	9	10	0	2	2
Kingston, Tenn.*	3	37	40	<1	3	3
Colorado River:						
Page, Ariz.	0	23	23	0	5	5
Parker Dam, Calif.-Ariz.	1	24	25	0	5	5
Columbia River:						
Wenatchee, Wash.	0	3	3	0	0	0
Pasco, Wash.*	20	347	367	0	1	1
Clatskanie, Ore.	17	48	65	0	<1	<1
Connecticut River:						
Enfield Dam, Conn.	1	4	5	0	0	0
Coosa River:						
Rome, Ga.	4	4	8	1	<1	1
Cumberland River:						
Cheatham Lock, Tenn.	1	4	5	0	0	0
Delaware River:						
Philadelphia, Pa.	1	3	4	0	0	0
Great Lakes:						
Duluth, Minn.	0	3	3	0	0	0
Green River:						
Dutch John, Utah	0	15	15	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	1	5	6	0	0	0
Illinois River:						
Peoria, Ill.	2	12	14	1	2	3
Grafton, Ill.	2	9	11	0	0	0
Kansas River:						
DeSoto, Kans.	1	17	18	0	3	3
Klamath River:						
Keno, Ore.	2	6	8	0	0	0
Maumee River:						
Toledo, Ohio	2	11	13	1	2	3
Mississippi River:						
St. Paul, Minn.	0	11	11	0	0	0
E. St. Louis, Ill.	3	11	14	0	1	1
New Roads, La.	11	6	17	2	0	2
New Orleans, La.	4	7	11	1	0	1
Missouri River:						
Williston, N. Dak.	1	17	18	0	3	3
Bismarck, N. Dak.	<1	15	15	0	2	2
St. Joseph, Mo.	3	13	16	1	3	4
North Platte River:						
Henry, Nebr.	4	54	58	0	35	35
Ohio River:						
Cairo, Ill.	7	7	14	2	1	3
Pend Oreille River:						
Albeni Falls Dam, Idaho	1	3	4	0	0	0
Platte River:						
Plattsmouth, Nebr.	3	18	21	1	6	7
Potomac River:						
Washington, D.C.	0	2	2	0	0	0
Red River, South:						
Alexandria, La.	6	14	20	1	1	2
Rio Grande:						
Laredo, Tex.	2	7	9	0	4	4
Sacramento River:						
Greens Landing, Calif.	2	13	15	1	7	8
San Joaquin River:						
Vernalis, Calif.	3	5	8	0	1	1
San Juan River:						
Shiprock, N. Mex.	18	10	28	5	4	9
Savannah River:						
Port Wentworth, Ga.*	4	11	15	<1	0	<1
Snake River:						
Payette, Idaho	2	9	11	0	5	5
Wawawai, Wash.	1	5	6	0	1	1
South Platte River:						
Julesburg, Colo.	18	67	85	5	52	57
Tennessee River:						
Chattanooga, Tenn.	4	10	14	2	2	4
Yellowstone River:						
Sidney, Mont.	4	13	17	0	3	3
Maximum	29	347	367	8	52	57
Minimum	0	2	2	0	0	0

* Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occuring radionuclides, common to all stations.

the Atchafalaya River, alpha radioactivity dropped to less than 15 pCi/liter on suspended solids. Pasco, Wash., on the Columbia River continued to show beta radioactivity on dissolved solids in excess of 150 pCi/liter.

Strontium–90 determinations and results

Beginning in 1959, strontium–90 analyses of the total solids in surface waters were made on 3-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except at those stations immediately below nuclear installations, where regular quarterly analyses were continued. The method used for determining strontium–90 is a modification of a procedure described by Harley (*8*). Yttrium–90 together with a yttrium carrier is precipitated as yttrium oxalate and the latter is washed, dried, weighted, and counted in a low-background anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium–90 concentrations in U.S. surface waters for the fourth quarter of 1965 and the first and second quarters of 1966. The stations are arranged in the table according to their distance from the headwaters. Table 3 presents a summary of these data.

While there are no standards for strontium–90 radioactivity of total solids in surface waters, the Public Health Service Drinking Water Standards set the limit for strontium–90 concentrations in drinking water at 10 pCi/liter.

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Table 2. Quarterly strontium-90 concentrations in surface waters, October–December 1965 and January–June 1966

Station	Average concentration (pCi/liter)		
	Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966
Allegheny River:			
Pittsburgh, Pa.	1.0		1.0
Animas River:			
Cedar Hill, N. Mex.		0.8	
Apalachicola River:			
Chattahoochee, Fla.		.9	
Arkansas River:			
Coolidge, Kans.		1.6	
Ponca City, Okla.	2.3		2.4
Fort Smith, Ark.		3.1	2.8
Little Rock, Ark.	2.7		
Pendleton Ferry, Ark.	3.1		2.8
Atchafalaya River:			
Morgan City, La.		1.6	
Bear River:			
Preston, Idaho		1.0	
Big Horn River:			
Hardin, Mont.	1.1		1.7
Big Sioux River:			
Sioux Falls, S. Dak.		2.3	
Chattahoochee River:			
Atlanta, Ga.	1.6		1.1
Lanett, Ala.		1.3	
Columbus, Ga.	1.0		1.0
Chena River:			
Fairbanks, Alaska	0.3		0.4
Clearwater River:			
Lewiston, Idaho		.2	
Clinch River:			
Clinton, Tenn.		.8	
Kingston, Tenn.	1.3	7.3	4.3
Colorado River:			
Loma, Colo.	.8		1.2
Page, Ariz.		2.2	
Boulder City, Nev.	2.7		2.5
Parker Dam, Calif-Ariz.			
Yuma, Ariz.	1.5		2.1
Columbia River:			
Northport, Wash.		1.0	
Wenatchee, Wash.	1.4		.3
Pasco, Wash.	1.3		1.2
McNary Dam, Ore.	1.1		2.4
Bonneville, Ore.		.8	
Clatskanie, Ore.	.9		.4
Connecticut River:			
Wilder, Vt.		.9	
Northfield, Mass.	1.0		1.0
Enfield Dam, Conn.		1.0	
Coosa River:			
Rome, Ga.			
Cumberland River:			
Cheatham Lock, Tenn.		1.0	
Cuyahoga River:			
Cleveland, Ohio		1.9	
Delaware River:			
Martins Creek, Pa.	.8		1.0
Trenton, N. J.		1.1	
Philadelphia, Pa.	.9		1.0
Escambia River:			
Century, Fla.	1.0		.9
Great Lakes:			
Duluth, Minn.	.8		.7
Sault Ste. Marie, Mich.		.8	
Milwaukee, Wis.	.7		1.0
Gary, Ind.		1.7	
Port Huron, Mich.	1.1		1.4
Detroit, Mich.		.6	
Buffalo, N.Y.	2.3		2.3
Green River:			
Dutch John, Utah		2.3	
Hudson River:			
Poughkeepsie, N.Y.	1.8		1.8
Illinois River:			
Peoria, Ill.	1.3		1.7
Grafton, Ill.		2.0	
Kanawha River:			
Winfield Dam, W. Va.		.7	
Kansas River:			
DeSoto, Kans.	2.9		2.6
Klamath River:			
Keno, Ore.	1.0		1.3
Little Miami River:			
Cincinnati, Ohio		2.1	
Maumee River:			
Toledo, Ohio	1.8		1.6
Merrimack River:			
Lowell, Mass.		1.0	
Mississippi River:			
St. Paul, Minn.		.8	
Dubuque, Iowa	2.4		3.0
Burlington, Iowa		2.1	
E. St. Louis, Ill.	1.9		2.1
Cape Girardeau, Mo.		1.8	
W. Memphis, Ark.	2.0		2.4
Vicksburg, Miss.		1.8	
Delta, La.	2.1		2.2
New Roads, La.	1.8		2.3
New Orleans, La.		3.0	
Missouri River:			
Williston, N. Dak.	2.1		1.8
Bismarck, N.Dak.		1.9	
Yankton, S. Dak.	2.6		2.8
Omaha, Nebr.		2.6	
St. Joseph, Mo.	2.6		3.3
Kansas City, Kans.		2.4	
Missouri City, Mo.	2.7		2.5
St. Louis, Mo.		2.5	
Monongahela River:			
Pittsburgh, Pa.	1.3		1.1
North Platte River:			
Henry, Nebr.	.5		1.7
Ohio River:			
Toronto, Ohio	3.5		1.2
Addison, Ohio		1.3	
Huntington, W.Va.			.9
Cincinnati, Ohio		1.1	
Louisville, Ky.	1.6		1.3
Evansville, Ind.		1.1	
Cairo, Ill.	1.2		1.5
Ouachita River:			
Bastrop, La.		1.9	
Pend Oreille River:			
Albeni Falls Dam, Idaho	.7		.8
Platte River:			
Plattsmouth, Nebr.		1.6	
Potomac River:			
Williamsport, Md.	.7		.7
Great Falls, Md.		1.1	
Washington, D.C.		.6	
Rainy River:			
International Falls, Minn.	3.2		3.0
Baudette, Minn.	3.2		2.7
Raritan River:			
Perth Amboy, N.J.			
(5 feet below surface)			
(5 feet above bottom)			
Red River, North:			
Grand Forks, N. Dak.	5.9	5.6	6.0
Red River, South:			
Denison, Tex.		4.6	
Index, Ark.	4.0		4.2
Bossier City, La.			
Alexandria, La.	3.9		3.2
Rio Grande:			
Alamosa, Colo.	.5		1.5
El Paso, Tex.			
Laredo, Tex.	1.3		1.7
Brownsville, Tex.		1.6	
Roanoke River:			
John H. Kerr Resr. Dam, Va.	1.5		1.3
Sabine River:			
Ruliff, Tex.		1.4	
Sacramento River:			
Greens Landing, Calif.		.5	
St. Lawrence River:			
Massena, N. Y.		1.7	
San Joaquin River:			
Vernalis, Calif.	.6		1.6
San Juan River:			
Shiprock, N. Mex.	1.5		1.3
Savannah River:			
North Augusta, S.C.		.9	
Port Wentworth, Ga.	1.6	1.3	2.3
Schuylkill River:			
Philadelphia, Pa.		.9	
Shenandoah River:			
Berryville, Va.	.4		.5
Ship Creek:			
Anchorage, Alaska		.1	
Snake River:			
Payette, Idaho	.5		.5
Wawawai, Wash.	.4		.4
Ice Harbor Dam, Wash.		.5	
South Platte River:			
Julesburg, Colo.	1.0		

Table 2. Quarterly strontium-90 concentrations in surface waters, October–December 1965 and January–June 1966—Continued

Station	Average concentration (pCi/liter)			Station	Average concentration (pCi/liter)		
	Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966		Oct-Dec 1965	Jan-Mar 1966	Apr-June 1966
Spokane River:				Truckee River:			
Post Falls Dam, Idaho	....	.6		Farad, Calif	.9	....	.8
Susquehanna River:				Verdigris River:			
Sayre, Pa	....	.9		Nowata, Okla	3.6		
Conowingo, Md	....	....	1.0	Wabash River:			
Tennessee River:				New Harmony, Ind	.6	....	1.7
Lenoir City, Tenn	.8			Willamette River:			
Chattanooga, Tenn	1.0	.9	1.0	Portland, Ore	.3	....	.1
Bridgeport, Ala	....	....	.7	Yakima River:			
Pickwick Landing, Tenn	....	1.0		Richland, Wash	....	.3	
Tombigbee River:				Yellowstone River:			
Columbus, Miss	....	1.4		Sidney, Mont	....	1.8	

During the fourth quarter of 1965 and the first and second quarters of 1966, this standard was not exceeded. Comparison between the quarters is not feasible at all sampling locations because of fluctuations in sampling frequencies. Comparison with results prior to October 1964 should take into consideration an instrument recalibration which resulted in a lowering of strontium–90 values by 15 percent (*11*).

Table 3. Summary of strontium-90 in surface waters October–December 1965 and January–June 1966

Period	Total number of samples	Concentration (pCi/liter)			
		Maximum	Miminum	Median	Average
October-December 1965	60	ᵃ5.8±0.4	ᵃ0.2±0.1	1.2	1.6
January-March 1966	62	7.3± .4	.1± .1	1.2	1.3
April-June 1966	66	6.0± .6	.1± .1	1.5	1.6

ᵃ Two standard deviations counting error.

The highest result for the fourth quarter 1965 and the second quarter 1966 and the second highest result for the first quarter 1966 occurred at Grand Forks, N. Dak., on the Red River, North. The highest result for the first quarter was at Kingston, Tenn., on the Clinch River. This result (7.3 pCi/liter) is a weighted average of three results (31.8, 15.0, and 3.4 pCi/liter). The reason for these three determinations was the occurrence of an unusually high gross beta radioactivity (*12*) during this quarter. This value was very unusual for this station. The effectiveness and importance of monitoring the gross radioactivities are illustrated since there was no other indication of elevated strontium–90 concentrations. According to the Atomic Energy Commission, these high values were the result of a temporary low flow caused by a reservoir cleaning operation.

REFERENCES

(*1*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*2*) *Ibid.*, 1959 Edition.

(*3*) *Ibid.*, 1960 Edition.

(*4*) *Ibid.*, 1961 Edition.

(*5*) *Ibid.*, 1962 Edition.

(*6*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*7*) AMERICAN PUBLIC HEALTH ASSOCIATION: AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater, 11th Edition. New York, N.Y. (1960).

(*8*) HARLEY, J. H. Radiochemical determinations of strontium–90: Health and Safety Laboratory Manual of Standard Procedures (August 1962 Revision). U.S. Atomic Energy Commission, Radiochemistry and Environmental Studies Division, HASL, New York Operations Office (1962).

(*9*) STRAUB, C. P. Significance of radioactivity data. JAWWA 53:704 (June 1961).

(*10*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*11*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Gross radioactivity and strontium–90 in surface waters of the United States, January 1965. Radiol Health Data 6:393–396 (July 1965).

(*12*) FEDERAL WATER POLLUTION CONTROL ADMINISTRATION. Gross radioactivity in surface waters of the United States, March 1966. Radiol Health Data Rep 7:514–516 (September 1966).

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Radioactivity in Washington Surface Water July 1965–June 1966[1]

Washington State Department of Health

Radioanalysis of surface water samples collected throughout the State of Washington is one of the major functions of the Washington State Department of Health radiation surveillance program. Most surface water samples are collected quarterly or semiannually by the Washington Pollution Control Commission from 71 stations located on 56 rivers throughout the State. Selected stations on the Columbia River are sampled weekly or monthly by local health departments. Cedar River, a major water supply for the greater Seattle area, is sampled monthly by the City of Seattle Water Department.

All surface water samples are collected as grab samples in 2-liter polyethylene bottles. To prevent loss of radioactivity to the container, 2 milliliters of concentrated nitric acid are added to the sample before shipment to the Washington State Department of Health laboratory in Seattle for analysis.

Analytical procedures

Surface water samples are divided into two groups; those samples coming from the Columbia River and those samples coming from waters other than the Columbia River. The latter samples are placed in stainless-steel Marinelli beakers for gamma-ray spectroscopy analysis as soon after receipt as possible. Distilled water is added when necessary to obtain a standardized counting geometry of 2 liters. Table 1 gives the gamma-ray efficiencies and detection limits for the gamma-ray spectrometer. After gamma-ray analysis, the samples are filtered through Whatman No. 42 filter paper. The filter paper containing the suspended solids is ashed in a muffle furnace, transferred to a tared planchet, weighed, and

Table 1. Beta-particle and gamma-ray efficiencies and detectability limits for the Washington State analysis

Radionuclide	Energy band (MeV)	Efficiency (percent)	Average background (cpm)	Detectability limits (pCi)
Beta particle				
Strontium-90–yttrium-90	----------	34	0.7	[a]0.31
Yttrium-90	----------	38	.7	[a] .28
Phosphorus-32	----------	35	.7	[a] .30
Gamma-ray				
Chromium-51	0.30–0.36	0.50	23.56	[b]200
Ruthenium-106	.44– .56	.91	23.03	[b]100
Cesium-137	.62– .72	2.50	11.57	[b]30
Zirconium-95	.73– .79	4.40	5.87	[b]20
Zinc-65	1.05–1.17	.98	6.47	[b]50

[a] Amount of radioactivity necessary to produce a net cpm equal to 2σ of background, based on 100-minute counts.

[b] Amount of radioactivity necessary to produce a net cpm equal to 4σ of the respective background, based on 100-minute counts. These detectability limits are given in pCi. To convert to pCi/liter, the volume of the sample must be taken into consideration.

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[1] Summarized from "Environmental Radiation Surveillance in Washington State," Fifth Annual Report, December 1966.

counted for gross beta radioactivity. The filtrate is evaporated to near dryness, quantitatively transferred to a tared planchet, dried, weighed, and counted for gross beta radioactivity.

Columbia River water is analyzed for gamma-ray activity approximately 14 days after collection. This delay allows the short-lived radionuclides, sodium–24, arsenic–76 and neptunium–239, to decay, leaving a less complex spectrum which can be evaluated without computer assistance. Following gamma-ray analysis the Columbia River samples are divided into two aliquots for further analysis. One aliquot is prepared for phosphorus–32 analysis and the other is analyzed for gross beta radioactivity by the methods described above. Gross beta-particle counting for all samples is performed 18 days after collection.

The phosphorus–32 analysis, a modification of published methods (*1–4*), begins 15 days after sample collection to allow arsenic–76 and other short-lived radionuclides to decay. The phosphorus is separated from interfering nuclides by precipitation as ammonium phosphomolybdate from an acid medium. The precipitate is washed with ammonium nitrate, dissolved with 3*N* ammonium hydroxide, transferred to a tared planchet, dried, ashed at 450° C., and counted for beta radioactivity.

Results

Table 2 presents the monthly average results for the Columbia River stations which are sampled routinely. In averaging, a less-than value is assumed to be equal to its numerical value and a less-than sign is placed in front of the average.

Table 3 summarizes the beta radioactivity measurements from the 63 other surface water stations from July 1965 through June 1966. The second column in this table gives code numbers and the abbreviations denoting geographical sections (figure 1). Each river is assigned a four digit number; the first two digits

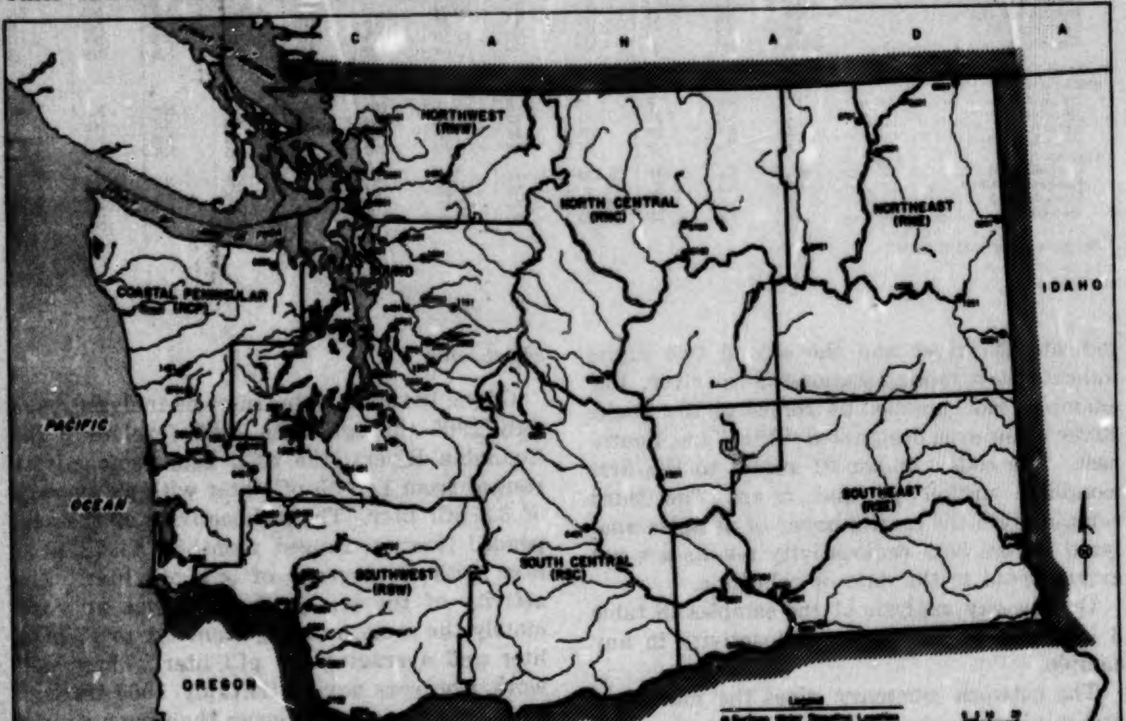

Figure 1. Washington surface water sampling locations with code numbers

Table 2. Monthly average radioactivity in Columbia River water, July 1965–June 1966

Location and type of analysis	Concentration (pCi/liter)											
	1965						1966					
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Richland (Code No. RSE 0106)												
Beta-particle												
Suspended [a]	12	50	1,805	94	26	34	18	17	31	41	21	34
Dissolved [a]	49	63	881	234	346	189	165	222	265	224	96	130
Total [a]	61	113	2,686	328	372	223	183	239	296	265	117	164
Phosphorus-32 [b]	67	68	1,294	330	104	283	166	207	315	318	116	68
Gamma-ray [b]												
Chromium-51	2,674	2,814	11,626	9,060	8,377	7,438	7,530	8,793	7,917	13,080	2,958	1,710
Ruthenium-106 [a]	< 75	<100	<102	<117	155	123	<122	<100	<100	158	<100	<100
Zirconium-95	< 15	< 20	< 16	< 20	< 20	< 20	< 30	< 20	< 20	< 20	< 20	< 20
Zinc-65	70	122	244	328	152	244	193	338	310	546	140	123
Pasco (Code No. RSE 0101)												
Beta-particle												
Suspended [a]	17	19	40	57	38	45	18	21	28	53	NS	20
Dissolved [a]	30	75	57	138	169	137	96	197	172	264	NS	21
Total [a]	47	94	97	195	207	182	114	218	200	317	NS	41
Phosphorus-32 [b]	NS	57	56	151	233	106	119	284	226	407	NS	18
Gamma-ray [b]												
Chromium-51	1,906	2,549	5,026	7,279	5,893	4,080	4,318	7,083	4,857	8,491	NS	319
Ruthenium-106 [a]	< 50	60	< 50	< 50	75	< 50	< 50	78	76	82	NS	< 50
Zirconium-95	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	NS	< 10
Zinc-65	74	87	87	129	142	246	138	306	333	335	NS	75
McNary Dam (Code No. RSE 0102)												
Beta-particle												
Suspended [a]	NS	NS	19	NS	NS	14	NS	NS	10	NS	NS	10
Dissolved [a]	NS	NS	37	NS	NS	56	NS	NS	80	NS	NS	23
Total [a]	NS	NS	56	NS	NS	70	NS	NS	90	NS	NS	33
Phosphorus-32 [b]	NS	NS	41	NS	NS	60	NS	NS	110	NS	NS	26
Gamma-ray [b]												
Chromium-51	NS	NS	3,064	NS	NS	2,253	NS	NS	2,816	NS	NS	677
Ruthenium-106 [a]	NS	NS	< 50	NS	NS	55	NS	NS	< 50	NS	NS	78
Zirconium-95	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10
Zinc-65	NS	NS	< 25	NS	NS	52	NS	NS	138	NS	NS	61
Washougal (Code No. RSW 0909)												
Beta-particle												
Suspended [a]	15	NS	8	7	8	7	NS	NS	NS	NS	NS	NS
Dissolved [a]	17	NS	21	31	37	32	NS	NS	NS	NS	NS	NS
Total [a]	32	NS	29	38	45	39	NS	NS	NS	NS	NS	NS
Phosphorus-32 [b]	14	NS	19	27	46	40	NS	NS	NS	NS	NS	NS
Gamma-ray [b]												
Chromium-51	960	NS	2,141	2,122	1,918	2,178	NS	NS	NS	NS	NS	NS
Ruthenium-106 [a]	< 50	NS	< 50	< 50	< 50	< 50	NS	NS	NS	NS	NS	NS
Zirconium-95	< 10	NS	< 10	< 10	< 10	< 10	NS	NS	NS	NS	NS	NS
Zinc-65	43	NS	< 25	< 25	< 25	< 25	NS	NS	NS	NS	NS	NS

See footnotes at end of table.

indicate the river and the second two digits indicate the sampling stations on the river. For example, code number 04 refers to the Snake River in the area designated "RSE," i.e., Southeast. The code number 01 refers to the first sampling station on that river. The third column gives the total number of samples analyzed. Gross beta radioactivity results are not extrapolated to the date of collection.

Gamma-ray analysis of the samples in table 3 indicated no detectable radioactivity in any sample.

The network summary gives the maximum and minimum values for the 184 samples analyzed, while the network average is obtained by averaging all the station average values.

Discussion

Of the 184 river water samples analyzed from July 1965 through June 1966 (excluding the Columbia River), the total beta radioactivity ranged from 1 to 95 pCi/liter with an average of 3.8 pCi/liter. The radioactivity of the suspended fraction ranged from <1 to 78 pCi/liter with an average of <1 pCi/liter. The activity of the soluble fraction was approximately the same, ranging from <1 to 17 pCi/liter and averaging 2.4 pCi/liter. These network averages during the July 1965 through June 1966 period were lower than the averages for the preceding 12 months.

Table 2. Monthly average radioactivity in Columbia River water, July 1965–June 1966—Continued

Location and type of analysis	Concentration (pCi/liter)											
	1965						1966					
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Northport (Code No. RNE 0801)												
Beta-particle												
Suspended [a]	< 1	NS	< 1	NS	NS	< 1	NS	NS	< 1	NS	NS	1
Dissolved [a]	2	NS	5	NS	NS	3	NS	NS	3	NS	NS	3
Total [a]	< 3	NS	< 6	NS	NS	< 4	NS	NS	< 4	NS	NS	4
Phosphorus-32 [b]	< 1	NS	< 1	NS	NS	< 1	NS	NS	< 1	NS	NS	< 1
Gamma-ray [b]												
Chromium-51	<100	NS	<100	NS	NS	<100	NS	NS	<100	NS	NS	<100
Ruthenium-106 [c]	< 50	NS	< 50	NS	NS	< 50	NS	NS	< 50	NS	NS	< 50
Zirconium-95	< 10	NS	< 10	NS	NS	< 10	NS	NS	< 10	NS	NS	< 10
Zinc-65	< 25	NS	< 25	NS	NS	< 25	NS	NS	< 25	NS	NS	< 25
Wanapum Dam (Code No. RSC 1201)												
Beta-particle												
Suspended [a]	NS	NS	NS	NS	NS	NS	NS	NS	< 1	< 1	< 1	< 1
Dissolved [a]	NS	NS	NS	NS	NS	NS	NS	NS	3	3	3	3
Total [a]	NS	NS	NS	NS	NS	NS	NS	NS	< 4	< 4	< 4	< 4
Phosphorus-32 [b]	NS	NS	NS	NS	NS	NS	NS	NS	< 1	< 1	< 1	< 1
Gamma-ray [b]												
Chromium-51	NS	NS	NS	NS	NS	NS	NS	NS	<100	<100	<100	<100
Ruthenium-106 [c]	NS	NS	NS	NS	NS	NS	NS	NS	< 50	< 50	< 50	< 50
Zirconium-95	NS	NS	NS	NS	NS	NS	NS	NS	< 10	< 10	< 10	< 10
Zinc-65	NS	NS	NS	NS	NS	NS	NS	NS	< 25	< 25	< 25	< 25
Vancouver (Code No. RSW 0102)												
Beta-particle												
Suspended [a]	11	NS	9	8	9	9	8	12	8	11	15	13
Dissolved [a]	16	NS	22	29	34	27	28	40	33	31	29	14
Total [a]	27	NS	31	37	43	36	35	52	41	42	44	26
Phosphorus-32 [b]	14	NS	18	24	44	32	40	49	44	47	33	14
Gamma-ray [b]												
Chromium-51	985	NS	2,117	2,137	1,896	1,388	1,560	1,907	1,524	1,551	1,195	638
Ruthenium-106 [c]	< 50	NS	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Zirconium-95	< 10	NS	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Zinc-65	43	NS	< 25	< 25	< 25	< 25	43	59	57	50	93	64
Longview (Code No. RSW 0904)												
Beta-particle												
Suspended [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	8	6	6
Dissolved [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	19	18	11
Total [a]	NS	NS	NS	NS	NS	NS	NS	NS	NS	27	24	17
Phosphorus-32 [b]	NS	NS	NS	NS	NS	NS	NS	NS	NS	24	14	11
Gamma-ray [b]												
Chromium-51	NS	NS	NS	NS	NS	NS	NS	NS	NS	836	699	453
Ruthenium-106 [c]	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 50	< 50	< 50
Zirconium-95	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 10	< 10	< 10
Zinc-65	NS	NS	NS	NS	NS	NS	NS	NS	NS	< 27	< 25	< 36

[a] Activity at time of counting. Strontium-90 yttrium-90 calibration standard.
[b] Results extrapolated to date of sample collection.
[c] Net activity in the 0.44–0.86 MeV gamma-ray range is assumed to be only ruthenium-106.
NS, no sample reported.

Monthly average total beta radioactivity for the Columbia River stations below the Hanford Facility ranged from 17 to 328 pCi/liter with one exception which was 2,686 pCi/liter in September 1965. Monthly average concentrations of phosphorus-32 in the Columbia River water samples taken below the Hanford Facility ranged from 11 to 1,234 pCi/liter.

The gamma-ray emitters, ruthenium-106 and zirconium-95, were found in monthly average concentrations that ranged from <50 to 158 pCi/liter for ruthenium-106 and <10 to <20 pCi/liter for zirconium-95. The values for ruthenium-106 are probably a combination of ruthenium-103 and ruthenium-106. Two other radionuclides, chromium-51 and zinc-65, were found in detectable quantities in Columbia River water. Monthly averages for chromium-51 ranged from 11 to 13,650 pCi/liter, and for zinc-65 the range was <25 to 546 pCi/liter.

Although any standards for gross beta radioactivity must be very carefully applied, the standard for drinking water is 1,000 pCi/liter of gross beta radioactivity in the absence of strontium-90 and alpha-particle emitters (*5*). The standards for water from all dietary sources for the general population at large (*6*) are:

Chromium-51, 670,000 pCi/liter; ruthenium-106, 3,300 pCi/liter; zinc-65, 10,000 pCi/liter; phosphorus-32, 7,000 pCi/liter.

Table 2. Beta radioactivity in Washington surface water (except for Columbia River) July 1965–June 1966

Sampling location	Code number	Number of samples	Concentration (pCi/liter)								
			Suspended [a]			Dissolved [a]			Total		
			Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Baker River	RNW 0401	1	<1			3			4		
Cedar River	RPS 0301	12	<1	<1	<1	<1	<1	3	1	1	4
Chehalis River	RSW 0601	3	<1	<1	<1	1	<1	1	2	2	3
	RCP 0401	1	<1			1			2		
Chico Creek	RPS 3101	4	<1	<1	<1	2	2	3	3	3	4
Cloquallam River	RCP 0101	2	<1	<1	<1	1	1	1	1	2	2
Colville River	RNE 0601	3	<1	<1	<1	4	3	5	5	4	6
Coweeman River	RSW 0501	2	<1	<1	<1	5	2	8	6	3	9
Cowlitz River	RSW 0701	4	<1	<1	<1	2	<1	2	2	1	3
Deschutes River	RPS 1503	2	<1	<1	<1	2	1	3	2	2	3
Dosewallips River	RPS 2201	1	<1			<1			1		
Dungeness River	RCP 0301	1	<1			1			2		
Duwamish River	RPS 0601	2	<1	<1	<1	2	2	2	3	3	3
Goldsborough Creek	RPS 3001	1	<1			2			3		
Green River	RPS 0501	2	<1	<1	<1	<1	<1	1	1	1	2
Hamma Hamma River	RPS 2601	1	<1			<1			1		
Hoh River	RCP 0801	1	<1			1			2		
Humptulips River	RCP 0701	2	<1	<1	<1	1	<1	1	1	1	2
Issaquah Creek	RPS 2901	2	<1	<1	<1	2	2	2	3	3	3
Kalama River	RSW 0801	2	<1	<1	<1	<1	<1	1	1	1	2
Kettle River	RNE 0701	3	<1	<1	<1	2	2	3	3	3	3
Lake Washington	RPS 2801	1	<1			6			7		
Lake Whatcom	RNW 0601	3	<1	<1	3	4	3	5	5	4	6
Lewis River	RSW 0301	6	[b] <1	<1	<1	1	<1	3	2	1	3
Little Spokane River	RNE 1001	2	1	<1	2	5	3	6	6	4	8
Naches River	RSC 0401	5	<1	<1	<1	1	1	1	2	2	2
Naselle River	RCP 2201	6	[b] <1	<1	2	<1	<1	2	2	1	4
Newaukum River	RSW 0401	2	<1	<1	<1	1	1	1	2	2	2
Nisqually River	RPS 1401	4	<1	<1	<1	2	1	2	2	2	3
Nooksack River	RNW 0101	4	1	<1	2	3	2	4	4	3	6
North Fork, Stillaguamish River	RPS 1601	2	<1	<1	<1	3	2	4	4	3	5
Okanogan River	RNC 0102	2	1	<1	2	3	2	3	4	4	4
	RNC 0103	1	<1			3			4		
Pend Oreille River	RNE 0201	3	<1	<1	1	3	3	3	4	4	4
	RNE 0203	2	<1	<1	<1	4	3	4	4	4	5
Puyallup River	RPS 1301	2	30	1	[c] 78	10	2	17	40	3	95
	RPS 1302	6	2	<1	5	2	1	3	3	2	7
Quinault River	RCP 1401	1	<1			1			2		
Samish River	RNW 0301	2	<1	<1	<1	2	2	2	3	3	3
Sammamish River	RPS 0701	1	<1			2			3		
Sanpoil River	RNE 0901	4	<1	<1	<1	2	2	2	3	3	3
Satsop River	RCP 1201	4	<1	<1	<1	<1	<1	1	1	1	2
Skagit River	RNW 0201	6	<1	<1	<1	2	2	2	3	3	3
Skykomish River	RPS 1101	2	<1	<1	<1	4	2	5	4	3	6
Snake River	RSE 0401	4	<1	<1	1	4	3	5	5	4	6
	RSE 0402	4	1	<1	3	5	3	6	6	4	9
Snohomish River	RPS 0401	4	<1	<1	<1	2	2	2	3	3	3
Snoqualmie River	RPS 1201	2	<1	<1	<1	3	2	3	3	3	4
South Fork, Stillaguamish River	RPS 1001	2	<1	<1	<1	3	2	4	4	3	5
Spokane River	RNE 0801	2	<1	<1	<1	3	2	3	3	3	4
	RNE 0802	3	2	<1	4	3	2	4	5	3	8
Stillaguamish River	RPS 0301	2	<1	<1	<1	2	2	2	3	3	3
Sultan River	RPS 0901	4	<1	<1	<1	3	1	5	4	2	6
Tolt River	RPS 2001	4	<1	<1	<1	2	<1	5	2	1	6
	RPS 2002	1	<1			2			4		
Toutle River	RSW 0201	4	<1	<1	<1	2	1	2	2	2	3
Walla Walla River	RSE 0501	4	2	<1	4	6	4	8	8	7	10
Wenatchee River	RNC 0202	3	<1	<1	<1	2	2	3	3	3	4
White River	RPS 0801	2	<1	<1	<1	3	2	3	3	3	4
Wishkah River	RCP 2001	6	<1	<1	<1	<1	<1	<1	1	1	1
Wynoochee River	RCP 0601	2	<1	<1	<1	<1	<1	1	1	1	2
Yakima River	RSC 0201	2	<1	<1	<1	2	1	2	2	2	3
	RSE 0201	2	<1	<1	<1	4	3	4	4	4	5
Network summary		184	<1	<1	78	2.4	<1	17	3.8	1	95

[a] For averaging purposes, <1 is assumed to be equal to 0.5 pCi/liter. Averages less than 1 are recorded as <1.
[b] One analysis lost in laboratory, not included in average.
[c] Sample contained 4.2 g/liter of suspended matter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1962–June 1963	August 1964
July 1963–June 1964	February 1965
July 1964–June 1965	May 1966

REFERENCES

(1) KOLTHOFF and SANDELL. Textbook of Quantitative Inorganic Analysis, Revised Edition. The MacMillan Company, New York, N.Y. (1949) pp. 390–397; 713–717.

(2) HILLEBRAND, W. F. and G. LUNDELL. Applied Inorganic Analysis. John Wiley and Sons, Inc., New York, N.Y. (1953) pp. 694–710.

(3) FURMAN, N. H. Scotts' Standard Method of Analysis, 5th Edition, Vol. 1. Van Nostrand Co., Inc., New York, N.Y. (1944) pp. 694–697.

(4) HANFORD ATOMIC PRODUCTS OPERATION. Radiological chemical analysis: River analysis manual-phosphorus–32 determination. Hanford Facility, Richland, Wash.

(5) PUBLIC HEALTH SERVICE. Public Health Service drinking water standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (August 1963).

(6) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of Committee II on Permissible Dose for Internal Radiation. Pergamon Press, New York, N.Y. (1959).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
HASL Fallout Network	July–December 1965	September 1966
HASL 80th Meridian Network	Calendar Year 1965	January 1967
National Air Sampling Network [1]	October–December 1966 and Annual Summary	April 1967
Plutonium in Airborne Particulates	October–December 1966	May 1967

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[1] The National Air Sampling Network has discontinued the measurement of radioactivity on its air samples.

1. Radiation Surveillance Network
April 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity by the station operators. These estimates are made after the decay of radon and thoran daughter products and prior to submission of the samples for laboratory analysis. When high level are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during April 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Gross beta radioactivity in air and precipitation continued to be near or below detectable levels. No indication of fresh fission products was found on any of the samples analyzed in April 1967.

REFERENCE

(*1*) RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Public Health Service. Washington, D.C. 20201 (Distribution by official request).

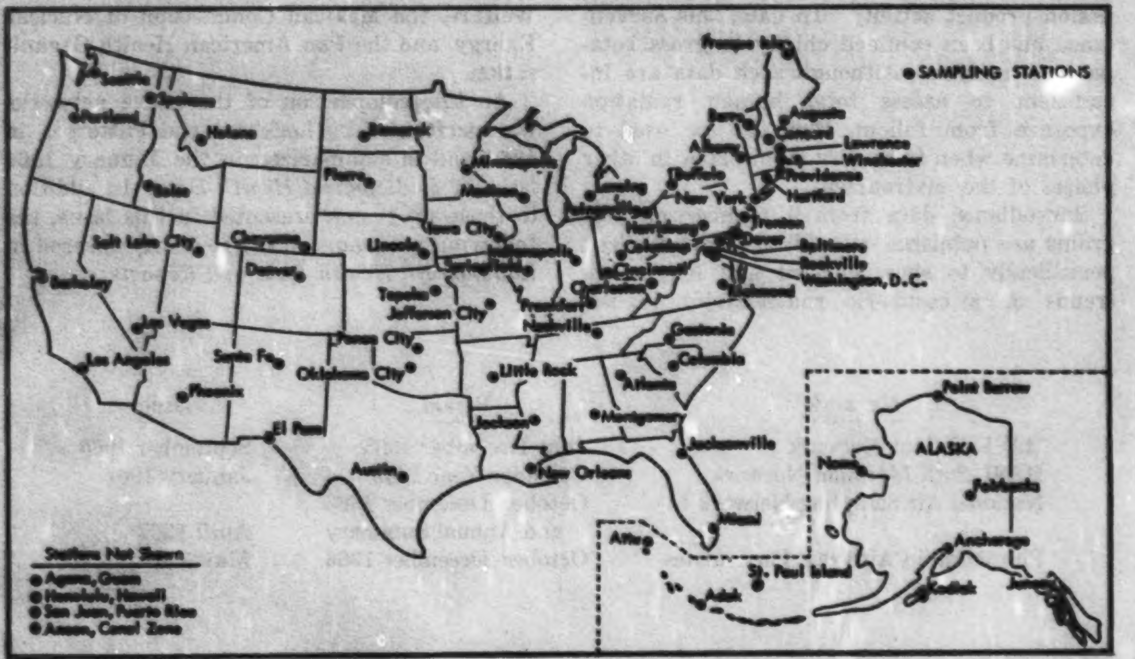
● SAMPLING STATIONS
Seattle
Spokane
Portland
Helena
Boise
Salt Lake City
Berkeley
Las Vegas
Los Angeles
Phoenix
Santa Fe
El Paso
Austin
Cheyenne
Denver
Bismarck
Pierre
Lincoln
Topeka
Jefferson City
Ponca City
Oklahoma City
Little Rock
Jackson
New Orleans
Minneapolis
Madison
Iowa City
Springfield
Indianapolis
Frankfort
Nashville
Lansing
Columbus
Cincinnati
Charleston
Harrisburg
Buffalo
Albany
New York
Presque Isle
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
Trenton
Dover
Baltimore
Rockville
Washington, D.C.
Richmond
Gastonia
Columbia
Atlanta
Montgomery
Jacksonville
Miami
ALASKA
Point Barrow
Nome
Fairbanks
Anchorage
Kodiak
Juneau
St. Paul Island
Adak
Attu
Stations Not Shown
● Agana, Guam
● Honolulu, Hawaii
● San Juan, Puerto Rico
● Ancon, Canal Zone

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, April 1967

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	30	1	0.20	0.03	0.17	Nov 66	30	< 6
Alaska:	Adak	30	------	.13	.00	.05	June 67	(c)	
	Anchorage	30	4	.12	.01	.05	Dec 66	5	< 1
	Attu Island	27	------	.10	.00	.05	July 67	(c)	
	Fairbanks	(b)	------	------	------	------	Jan 67	(c)	
	Juneau	16	3	.09	.00	.04	Apr 67	78	<18
	Kodiak	2	------	.05	.03	.04	May 67	(c)	
	Nome	(b)	------	------	------	------	Sept 66	(c)	
	Pt. Barrow	30	------	.12	.01	.07	Aug 67	(c)	
	St. Paul Island	(b)	------	------	------	------	Oct 66	(c)	
Ariz:	Phoenix	30	------	.60	.08	.21	Apr 67	(c)	
Ark:	Little Rock	25	7	.33	.05	.13	Dec 66	215	<43
Calif:	Berkeley	30	10	.15	.05	.06	May 67	133	<36
	Los Angeles	20	8	.14	.04	.07	Sept 66	95	<17
C.Z.:	Ancon	18	------	.05	.08	.08	May 67	(c)	
Colo:	Denver	30	8	.30	.08	.17	May 67	88	<18
Conn:	Hartford	26	11	.32	.00	.14	Apr 67	88	<19
Del:	Dover	30	------	.22	.05	.16	Nov 66	(c)	
D.C.:	Washington	30	7	.25	.01	.13	Aug 67	38	< 6
Fla:	Jacksonville	25	3	.31	.05	.16	Dec 66	16	< 3
	Miami	30	1	.30	.11	.20	Apr 67	10	< 2
Ga:	Atlanta	30	------	.35	.06	.19	Oct 66	(c)	
Guam:	Agana	27	------	.14	.03	.04	Nov 66	(c)	
Hawaii:	Honolulu	30	1	.30	.02	.08	July 67	35	< 7
Idaho:	Boise	28	10	.30	.04	.11	July 67	35	< 7
Ill:	Springfield	30	8	.49	.05	.14	Aug 67	73	<15
Ind:	Indianapolis	30	11	.30	.06	.15	Oct 66	90	<18
Iowa:	Iowa City	30	11	.22	.03	.12	May 67	128	<25
Kans:	Topeka	30	10	.31	.03	.14	Dec 66	161	<22
Ky:	Frankfort	24	8	.20	.03	.17	Aug 67	44	< 9
La:	New Orleans	30	3	.34	.06	.17	Aug 67	78	<16
Maine:	Augusta	30	11	.26	.03	.15	Sept 66	136	<26
	Presque Isle	6	------	.15	.06	.12	May 67	(c)	
Md:	Baltimore	30	3	.28	.02	.17	Apr 67	15	< 3
	Rockville	16	------	.21	.03	.12	July 67	(c)	
Mass:	Lawrence	30	10	.29	.03	.16	Nov 66	132	<26
	Winchester	18	9	.26	.02	.15	June 67	117	<23
Mich:	Lansing	30	10	.22	.01	.13	July 67	54	<11
Minn:	Minneapolis	19	7	.30	.03	.10	Nov 66	60	<12
Miss:	Jackson	28	3	.26	.01	.11	Sept 66	47	< 9
Mo:	Jefferson City	30	12	.33	.03	.11	Oct 66	91	<18
Mont:	Helena	30	7	.35	.00	.12	June 67	59	<12
Nebr:	Lincoln	13	8	.48	.01	.11	Oct 66	50	<10
Nev:	Las Vegas	27	------	.46	.06	.18	Jan 67	(c)	
N.H.:	Concord	19	------	.26	.03	.15	Aug 67	(c)	
N.J.:	Trenton	30	4	.25	.00	.12	Sept 66	16	< 3
N.Mex:	Santa Fe	30	1	.27	.04	.11	June 67	1	< 1
N.Y.:	Albany	30	9	.24	.00	.12	Oct 66	86	<13
	Buffalo	21	------	.30	.03	.11	May 67	(c)	
	New York City	25	------	.29	.01	.12	June 67	(c)	
N.C.:	Gastonia	29	6	.37	.03	.19	May 67	42	< 9
N.Dak:	Bismarck	30	9	.30	.06	.11	Aug 67	55	<11
Ohio:	Cincinnati	18	------	.37	.08	.14	Nov 66	(c)	
	Columbus	30	9	.35	.01	.19	Sept 66	80	<16
	Painesville	30	12	.30	.01	.14	Apr 67	73	<15
Okla:	Oklahoma City	29	9	.31	.02	.09	July 67	107	<23
	Ponca City	23	7	.12	.01	.05	Apr 67	56	<11
Oreg:	Portland	28	14	.15	.02	.07	Oct 66	71	<14
Pa:	Harrisburg	28	1	.30	.01	.11	Oct 66	21	< 4
P.R.:	San Juan	24	2	.32	.07	.16	Sept 66	40	< 8
R.I.:	Providence	25	10	.27	.01	.13	July 67	107	<21
S.C.:	Columbia	22	4	.28	.08	.15	June 67	38	<12
S.Dak:	Pierre	30	6	.35	.01	.13	Apr 67	29	< 6
Tenn:	Nashville	28	11	.34	.03	.13	July 67	73	<15
Tex:	Austin	30	5	.40	.05	.13	Nov 66	93	<19
	El Paso	28	1	.20	.04	.11	Aug 67	1	< 1
Utah:	Salt Lake City	30	11	.37	.11	.23	Sept 66	54	<11
Vt:	Barre	30	13	.31	.00	.13	Dec 66	76	<15
Va:	Richmond	30	6	.28	.02	.14	Dec 66	38	< 7
Wash:	Seattle	30	11	.13	.02	.07	Dec 66	62	<12
	Spokane	28	4	.22	.02	.10	Nov 66	13	< 3
W.Va:	Charleston	30	11	.32	.02	.13	June 67	86	<17
Wis:	Madison	25	12	.10	.00	.10	Dec 66	66	<15
Wyo:	Cheyenne	30	6	.31	.05	.13	Jan 67	64	<13
Network summary		1,836	398	.60	.00	.12	------	67	<14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

[b] No report received.

[c] No precipitation sample collected.

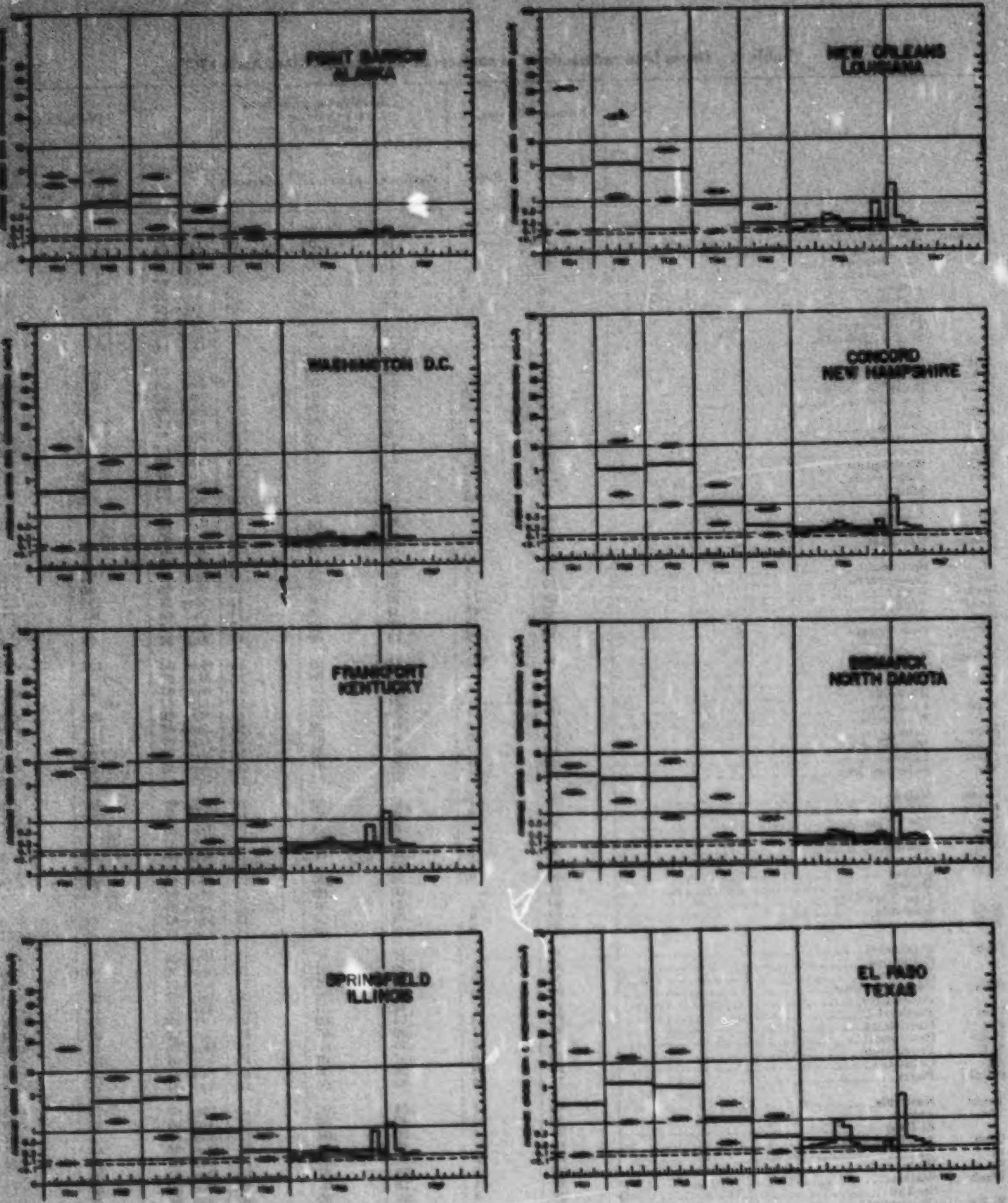

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1960–April 1967

2. Canadian Air and Precipitation Monitoring Program, April 1967[1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for April 1967 are presented in table 2.

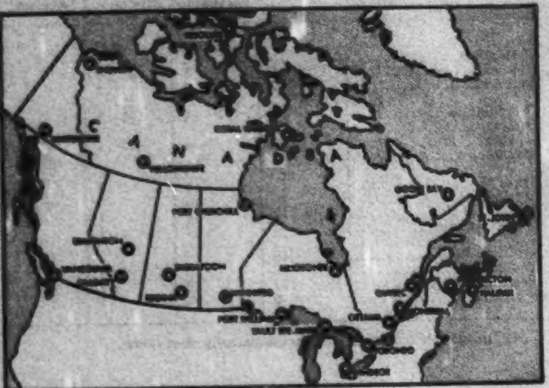

Figure 3. Canadian air and precipitation sampling stations

Table 2. Canadian gross beta radioactivity in surface air and precipitation, April 1967

Station	Number of samples	Air surveillance radioactivity (pCi/m³)			Precipitation measurement	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.3	0.1	0.2	57	1.6
Coral Harbour	28	.2	.0	.1	80	0.8
Edmonton	30	.2	.0	.2	63	.4
Ft. Churchill	30	.3	.1	.1	69	.4
Ft. William	30	.3	.0	.2	86	3.3
Fredericton	30	.3	.0	.1	55	1.2
Goose Bay	28	.2	.1	.2	52	1.3
Halifax	30	.3	.0	.2	31	2.0
Inuvik	30	.2	.0	.1	29	.2
Montreal	30	.4	.0	.2	41	2.0
Moosonee	30	.2	.0	.2	30	1.0
Ottawa	30	.3	.0	.2	48	3.3
Quebec	30	.2	.1	.1	46	2.4
Regina	30	.3	.0	.1	88	.7
Resolute	30	.2	.1	.1	NS	NS
St. John's, Nfld.	30	.3	.0	.1	23	2.5
Saskatoon	30	.3	.0	.1	100	.4
Saulte Ste Marie	30	.3	.0	.2	NS	NS
Toronto	29	.4	.0	.2	29	2.6
Vancouver	30	.2	.0	.1	37	2.1
Whitehorse	30	.2	.0	.1	22	.6
Windsor	30	.2	.0	.2	23	2.7
Winnipeg	30	.2	.0	.2	27	2.0
Yellowknife	30	.2	.0	.1	108	.2
Network summary	------	0.4	0.0	0.2	40	1.5

NS, no sample

REFERENCES

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*4*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*5*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*6*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

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[1] Prepared from information and data in the May 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Mexican Air Monitoring Program
April 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

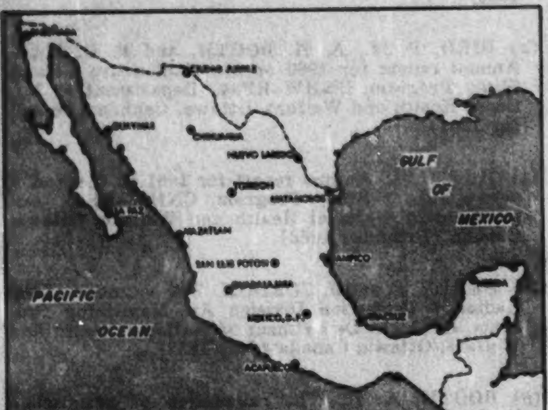

Figure 4. Fallout network sampling stations in Mexico

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days week at the rate of 1,000-cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, is has been found that a minimum of eight samples per month were needed to get a reliable average radioactivity at each station (7).

The maximum, minimum, and average fission product beta-particle concentrations in surface air during April 1967 are presented in table 4.

Table 4. Mexican gross beta radioactivity of airborne particulates, April 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	18	0.6	0.2	0.3
Chihuahua	15	.5	.1	.2
Ciudad Juáres	11	.3	.1	.2
Ensenada	7	.2	.1	.1
Guadalajara	9	.1	< .1	.1
Guaymas	NS			
La Paz	10	.4	< .1	.2
Matamoros	NS			
Mazatlán	14	.4	.1	.2
Mérida	10	.3	.1	.1
México, D.F.	18	.1	.1	.1
Nuevo Laredo	7	.2	.1	.1
San Luis Potosí	NS			
Tampico	13	.3	< .1	.1
Torreón	17	.3	.1	.1
Veracruz	9	.3	.1	.1

NS, no sample collected, station temporarily shut down.

REFERENCE

(7) VASQUEZ, M., and R. M. DE NULMAN. Estudios sobre la Radioactividad Ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear. Dirección General de Seguridad Radiológica (en pressa 1966).

4. Pan American Air Sampling Program April 1967

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiclogical health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling sites are shown in figure 5.

The April 1967 air monitoring results from the participating countries are given in table 4.

Table 4. Gross beta radioactivity in surface air, PAHO, April 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average ᵃ
Argentina: Buenos Aires	30	0.07	0.02	0.04
Bolivia: La Paz	NS			
Chile: Santiago	28	.05	.02	.03
Colombia: Bogota	30	.02	.00	.01
Ecuador: Guayaquil	22	.03	.00	.02
Jamaica: Kingston	NS			
Peru: Lima	30	.06	.01	.03
Venezuela: Carcas	15	.06	.01	.03
West Indies: Trinidad	18	.07	.01	.05
Pan American summary	143	0.07	0.00	0.03

ᵃ The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no report received.

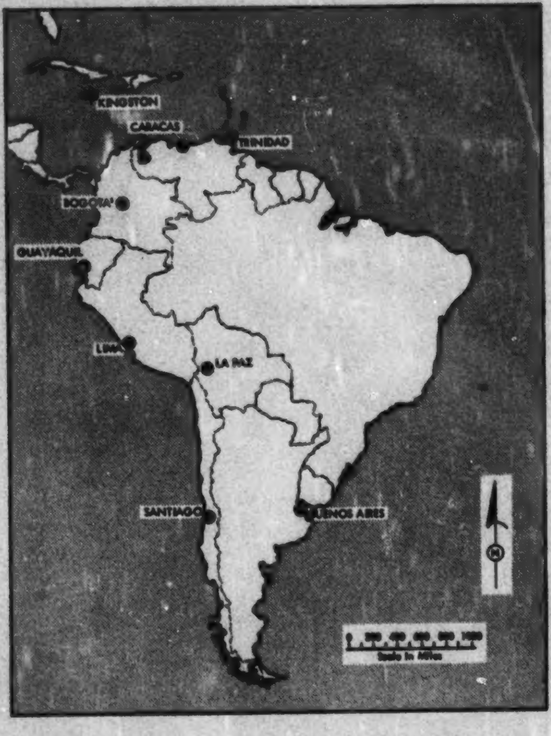

Figure 5. Pan American Air Sampling Program stations

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring in the vicinity of nuclear facilities.

Iodine-131 in Bovine Thyroids, January-March 1967

National Center for Radiological Health
Public Health Service

The National Center for Radiological Health established a Bovine Thyroid Network in October 1964 (*1*). Specimens are collected by the Meat Inspection Division, U.S. Department of Agriculture, and analyzed by gamma-ray spectroscopy for iodine-131 content at the Northeastern Radiological Health Laboratory, Winchester, Mass.

The network consists of collection areas (counties shaded in figure 1) located so as to cover, as nearly as possible, areas near major nuclear reactors, spent-fuel reprocessing plants, and nuclear test sites. Details of sampling and analysis have been published earlier (*1*). For this report, the collection areas sampled during January through March 1967 were grouped on a broad geographical basis as shown in figure 1.

The results for January through March 1967 appear in table 1 and are listed chronologically within the geographical groupings noted in figure 1; table 2 defines the State-County relationships. The influx of fallout iodine-131 following the mainland Chinese test of December 27, 1966, was observed throughout January 1967, declining to non-detectable levels by mid February 1967. Values greater than 500 pCi/g for individual specimens were observed in several of the geographical groupings sampled during the peak periods in January. Peak concentrations in individual bovine thyroids ranged from about 600 to 3,260 pCi/g in those areas that were sampled and where elevated thyroid levels were observed (grouping 1, particularly the central California counties; grouping 2; grouping 3; grouping 4; grouping 6).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1966	January 1967
July–December 1965	April 1967

REFERENCE

(*1*) BARATTA, E. J., E. R. WILLIAMS, and G. MURRAY. Iodine-131 in bovine thyroids, October-December 1964. Radiol Health Data 6:569–574 (October 1965).

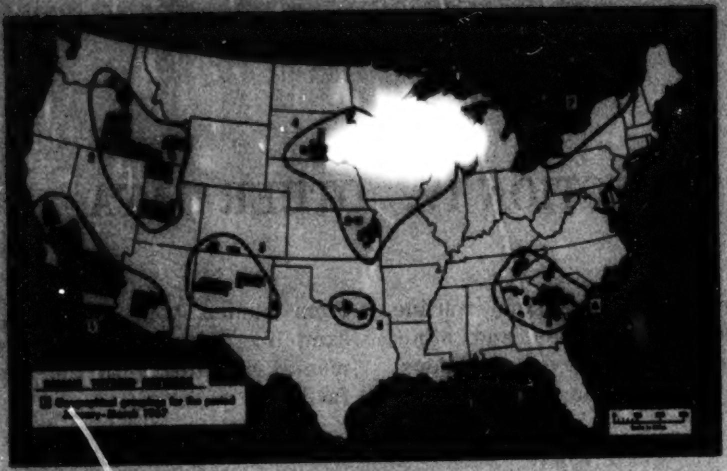

Figure 1. Counties sampled in bovine thyroid network, January-March 1967

Table 1. Iodine-131 in bovine thyroids, January-March 1967

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
1 Arizona and California	1/3	Merced	3	5	ND	9
		Riverside	5	1	ND	4
		Stanislaus	2	ND		
	1/4	Monterey	2	5	ND	9
		San Bernardino	2	3	2	4
	1/6	Maricopa	2	ND		
		Orange	2	6	5	7
	1/9	San Joaquin	1	34		
		Stanislaus	2	25	26	30
	1/10	Monterey	2	367	249	485
		Riverside	5	24	ND	117
		San Joaquin	1	10		
	1/12	Maricopa	2	9	9	9
	1/13	Merced	2	266	188	997
	1/16	Kings	1	ND		
		San Bernardino	7	11	ND	34
		San Joaquin	2	18	3	32
	1/19	Los Angeles	1	24		
	1/20	Maricopa	2	ND		
	1/23	Merced	2	520	10	1,030
		Monterey	4	124	9	454
		Stanislaus	1	3,260		
		Tulare	1	7		
	1/24	San Bernardino	5	6	ND	25
	1/25	San Joaquin	2	58	11	104
		Santa Cruz	2	317	4	630
	1/26	Santa Cruz	2	1	ND	2
		San Bernardino	7	ND		
	1/30	Merced	2	13	ND	20
		Monterey	2	49	ND	98
		Stanislaus	2	47	ND	94
	1/31	San Joaquin	2	2	ND	3
		Stanislaus	2	55	2	133
	2/1	San Bernardino	2	ND		
	2/2	Santa Cruz	2	22	31	32
	2/3	Los Angeles	5	<1	ND	2
	2/6	Fresno	1	ND		
		Merced	4	180	3	313
		San Bernardino	5	ND		
		Stanislaus	3	357	80	688
	2/7	Los Angeles	1	ND		
		Monterey	3	ND		
		San Bernardino	1	ND		
		San Joaquin	2	3	ND	5
	2/10	Maricopa	2	ND		
		Orange	2	1	ND	3
	2/13	Merced	2	0	ND	17
		Monterey	2	2	ND	3
		Stanislaus	2	55	ND	175
	2/14	San Joaquin	2	9	ND	18
		Stanislaus	2	3	ND	5

See footnotes at end of table.

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Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping a	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid		
				Average or concentration	Minimum	Maximum
1 Continued	2/15	Santa Cruz	2	ND		
	2/16	San Bernardino	2	< 1	ND	2
	2/17	Kings	2	ND		
		Los Angeles	2	ND		
	2/20	Merced	2	160	30	279
		Monterey	2	4	ND	7
		Stanislaus	2	ND		
	2/21	San Bernardino	5	1	ND	2
		San Joaquin	2	2	ND	5
		Stanislaus	2	65	48	87
	2/23	Los Angeles	2	1	ND	3
	2/24	Maricopa	2	ND		
		Orange	2	4	ND	7
		Tulare	2	ND		
	2/27	Merced	4	2	ND	7
		Monterey	2	64	ND	128
		San Bernardino	2	ND		
	2/28	San Bernardino	4	ND		
		San Joaquin	2	1	ND	2
		Stanislaus	2	5	ND	9
	3/1	San Bernardino	1	ND		
	3/3	Maricopa	2	ND		
		Kings	2	2	2	2
	3/6	Fresno	2	3	ND	5
		Merced	2	ND		
		Orange	2	ND		
		Stanislaus	2	ND		
	3/7	San Bernardino	5	< 1	ND	2
		San Joaquin	2	6	ND	12
		Stanislaus	2	11	10	12
	3/9	Merced	1	ND		
		Stanislaus	1	ND		
	3/10	Maricopa	3	ND		
		Los Angeles	4	ND		
	3/13	Fresno	2	ND		
		Merced	2	ND		
		Monterey	2	32	ND	64
	3/14	Monterey	2	ND		
		Stanislaus	2	ND		
	3/16	Kern	5	48	26	75
	3/17	Maricopa	2	6	ND	11
		Ventura	2	ND		
	3/20	Merced	2	2	ND	3
		Monterey	2	ND		
		Stanislaus	2	ND		
	3/21	San Joaquin	4	ND		
		Stanislaus	2	ND		
	3/22	Maricopa	2	ND		
		San Bernardino	3	ND		
	3/23	San Bernardino	1	ND		
	3/27	Monterey	2	ND		
		Stanislaus	4	6	ND	15
	3/28	San Bernardino	1	ND		
		San Joaquin	3	7	ND	13
		Stanislaus	2	5	4	5
	3/29	San Bernardino	1	ND		
	3/30	Los Angeles	2	ND		
		Orange	2	1	ND	2
	3/31	Tulare	2	ND		
9 Idaho, Oregon, Utah, and Washington	1/6	Bannock	5	54	ND	97
		Canyon	5	14	11	18
	1/11	Ada	5	80	2	165
		Millard	3	336	286	367
	1/12	Sevier	2	19	17	20
	1/18	Sanpete	5	14	6	28
	1/20	Canyon	2	28	25	30
		Gem	6	28	4	48
		Payette	2	562	313	810
	1/25	Cassia	5	2	2	3
	1/26	Sevier	5	44	17	97
	1/30	Walla Walla	7	354	6	1,004
	1/31	Sanpete	5	5	3	6
	2/1	Bingham	5	ND		
	2/7	Bonneville	5	ND		
	2/8	Canyon	2	12	5	10
		Gem	2	132	5	352
	2/14	Davis	5	2	ND	5
		Owyhee	1	ND		
	2/15	Owyhee	1	ND		
	2/16	Ada	2	ND		
		Owyhee	1	ND		
	2/21	Ada	2	ND		
		Gem	2	2	ND	3
	2/23	Owyhee	1	40		
	2/24	Malheur	1	ND		
	3/3	Walla Walla	10	44	ND	140

See footnotes at end of table.

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Table 2. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping ᵃ	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid: Average of concentration	Minimum	Maximum
2 Continued	3/7	Ada	1	ND		
	[illegible]	Canyon	1	ND		
	3/13	Ada	[illegible]	ND		
	[illegible]	Walla Walla	[illegible]	ND		
	3/17	[illegible]	[illegible]	ND		
	[illegible]	[illegible]	[illegible]	< 1	ND	2
	[illegible]	[illegible]	[illegible]	1	ND	2
	[illegible]	Canyon	10	< 1	ND	2
	[illegible]	[illegible]	[illegible]	1	ND	3
	[illegible]	[illegible]	1	ND		
	[illegible]	Canyon	1	ND		
	[illegible]	[illegible]	1	ND		
		Twin Falls	1	3		
		[illegible]	1	ND		
		Washington	1	ND		
3 Colorado, New Mexico, and Western Texas	1/3	Conejos	[illegible]	2	ND	[illegible]
	1/5	Bernalillo	[illegible]	1	ND	[illegible]
	1/9	Valencia	[illegible]	12	4	17
	1/10	San Miguel	[illegible]	457	118	[illegible]
	[illegible]	Bernalillo	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	Bernalillo	[illegible]	[illegible]	[illegible]	[illegible]
	1/17	Bernalillo	[illegible]	267	[illegible]	[illegible]
	1/20	Bernalillo	[illegible]	10	5	18
	1/24	La Plata	[illegible]	ND		
	2/3	Bernalillo	[illegible]	ND		
	2/7	Bernalillo	[illegible]	ND		
	2/21	Bailey	[illegible]	[illegible]		
4 Iowa, Kansas, South Dakota, and Wisconsin	1/6	Miner	[illegible]	12	2	19
		Turner	[illegible]	12	12	13
	1/9	Anderson	[illegible]	166	[illegible]	371
	1/10	Rock	[illegible]	4	ND	9
		Tripp	1	621		
	1/11	Hanson	1	[illegible]		
		Lake	1	[illegible]		
		Lyon (Iowa)	1	ND		
	1/13	Clay	[illegible]	82	46	[illegible]
		Dane	[illegible]	1	ND	3
	1/17	McCook	10	178	91	687
	1/18	Franklin	1	64		
	1/20	Dane	[illegible]	6	6	6
	1/24	Lake	[illegible]	7	4	8
		Lyon (Iowa)	[illegible]	34	10	97
	1/25	Green	1	17		
		Johnson	[illegible]	22	20	28
		Rock	[illegible]	3	ND	14
	1/27	Grant	[illegible]	ND		
		Rock	[illegible]	ND		
	1/31	Lake	[illegible]	15	5	20
	2/2	Lyman	1	157		
		Mellette	1	144		
		Osage	1	15		
	2/3	Lyon (Kansas)	[illegible]	3	2	4
		Rock	[illegible]	ND		
	2/6	Rock	[illegible]	ND		
	2/8	Yankton	[illegible]	6	3	10
	2/13	Dane	[illegible]	ND		
	2/17	Douglas	[illegible]	10	9	10
	2/20	Dane	[illegible]	ND		
		Rock	[illegible]	ND		
	2/21	Gregory	[illegible]	ND		
	2/22	Rock	[illegible]	ND		
	2/23	Leavenworth	[illegible]	ND		
	2/27	Dane	[illegible]	ND		
		Rock	[illegible]	1	ND	4
	3/1	Brule	1	4		
		Johnson	[illegible]	6	ND	27
		Lyon (Iowa)	[illegible]	22	3	40
		Woodson	[illegible]	ND		
	3/3	Rock	[illegible]	ND		
	3/4	Gregory	[illegible]	ND		
		Roberts	[illegible]	1	ND	2
	3/6	Lake	[illegible]	ND		
		Turner	[illegible]	9	6	12
	3/8	Minnehaha	1	9		
	3/10	Miami	[illegible]	5	2	8
	3/13	Lyman	[illegible]	6	5	7
		Mellette	1	3		
	3/15	Franklin	[illegible]	6	3	10
		McCook	[illegible]	ND		
	3/17	Lyon (Kansas)	1	3		
		Pottawatomie	1	ND		
	3/21	Aurora	1	ND		
		Hyde	[illegible]	ND		
	3/23	Rock	[illegible]	ND		
	3/24	Rock	[illegible]	1	ND	2
		Wyandotte	1	ND		
	3/28	Gregory	[illegible]	ND		
		Miner	1	ND		
		Roberts	[illegible]	ND		
	3/29	Douglas	[illegible]	[illegible]	ND	4

ᵃ See footnotes at end of table.

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Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping ᵃ	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid: Average or concentration	Minimum	Maximum
4 Continued	2/20	[illegible]	[illegible]	ND		
	2/21	Franklin	1	ND		
		Leavenworth	1	ND		
5 Oklahoma and Eastern Texas	2/23	Carter	1	6		
	2/27	[illegible]	1	ND		
6 Georgia, North Carolina, South Carolina and Tennessee	1/3	[illegible]	1	5		
		McCormick	1	4		
		[illegible]	1	4		
		Spartanburg	1	4		
		[illegible]	1	ND		
		Warren	1	ND		
		Wilkes	[illegible]	[illegible]	4	6
	1/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1/9	[illegible]	10	[illegible]	4	1,0[illegible]
	1/10	[illegible]	[illegible]	[illegible]	676	1,0[illegible]
	1/16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1/17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1/24	[illegible]	[illegible]	[illegible]	84	904
	1/26	[illegible]	[illegible]	[illegible]	195	[illegible]
	1/31	[illegible]	[illegible]	[illegible]	9	[illegible]
	2/7	[illegible]	[illegible]	[illegible]	ND	[illegible]
	2/14	[illegible]	[illegible]	[illegible]	27	[illegible]
	2/21	[illegible]	[illegible]	ND		
	2/22	[illegible]	[illegible]	[illegible]	4	[illegible]
	2/28	[illegible]	[illegible]	[illegible]		
	3/7	[illegible]	[illegible]	[illegible]	[illegible]	3
		[illegible]	[illegible]	[illegible]	ND	4

See footnotes at end of table.

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Table 1. Iodine-131 in bovine thyroids, January–March 1967—Continued

Geographical grouping [a]	Date of slaughter	County of origin	Number of samples	pCi iodine-131/g thyroid: Average of concentration	Minimum	Maximum
6 Continued		[illegible]	2	3	ND	3
		[illegible]	[illegible]	ND		
		[illegible]	[illegible]	3	ND	6
	[illegible]	[illegible]	10	4	ND	11
	[illegible]	[illegible]	[illegible]	ND		
		[illegible]	[illegible]	3		
		[illegible]	[illegible]	3	ND	7
		[illegible]	[illegible]	17		
	[illegible]	[illegible]	[illegible]	ND		
		[illegible]	[illegible]	1	ND	3
		[illegible]	[illegible]	1	ND	3
		[illegible]	[illegible]	ND		
		[illegible]	[illegible]	3	ND	2
		[illegible]	[illegible]	4	3	4
		[illegible]	[illegible]	6		
		[illegible]	[illegible]	6		
	[illegible]	[illegible]	[illegible]	8		
		[illegible]	[illegible]	4	ND	7
		[illegible]	[illegible]	ND		
		[illegible]	[illegible]	ND		
		[illegible]	[illegible]	3	4	6
		[illegible]	[illegible]	ND		
	[illegible]	[illegible]	[illegible]	3		
7 New York and Vermont	1/11	Chautauqua	10	3	ND	15
		Franklin	10		ND	3
	1/16	Chautauqua	10	3	ND	6
	[illegible]	Franklin	10	ND		
	[illegible]	Chautauqua	10	1	ND	8
	2/1	Chautauqua	10	1	ND	5
	2/8	Chautauqua	10	ND		
		Franklin	10	ND		
	[illegible]	Franklin	[illegible]	ND		
	[illegible]	Franklin	7	ND		
	[illegible]	Chautauqua	10	ND		
	[illegible]	Chautauqua	10	<1	ND	2
		Franklin	10	ND		
	[illegible]	Chautauqua	10	ND		
	[illegible]	Franklin	10	ND		
	[illegible]	Chautauqua	10	ND		

[a] Geographical areas as designated in figure 1, encompassing those counties that were sampled in the States indicated.

ND, nondetectable: the two standard deviation counting error was greater than or equal to the concentration observed. For the counting system utilized and these very low concentrations the two standard deviation counting errors were generally 1–3 pCi/g thyroid.

Table 2. State-county relationships

State	County	County
Arizona	Maricopa Santa Cruz	
California	Fresno Kern Kings Los Angeles Merced Monterey Orange	Riverside San Bernardino San Joaquin Santa Cruz Stanislaus Tulare Ventura
Colorado	Conejos La Plata	
Georgia	Burke Bulloch Chattooga Cherokee Columbia Emanuel Forsyth Gordon Glascock Jenkins	McDuffie Newton Pickens Richmond Screven Toombs Upson Walton Warren Wilkes
Idaho	Ada Bannock Bingham Bonneville Canyon Cassia	Gem Jerome Owyhee Payette Twin Falls Washington
Iowa	Lyon	
Kansas	Anderson Clay Douglas Franklin Johnson Leavenworth	Lyon Miami Osage Pottawatomie Woodson Wyandotte
North Carolina	Cleveland	
New York	Chautauqua	
New Mexico	Bernalillo San Miguel Valencia	
Oklahoma	Carter	
Oregon	Malheur Wallowa	
South Carolina	Abbeville Aiken Bamberg Barnwell Cherokee Dorchester Edgefield	Greenwood Lexington McCormick Orangeburg Saluda Spartanburg
South Dakota	Aurora Brule Gregory Hanson Hyde Lake Lyman McCook	Mellette Miner Minnehaha Roberts Tripp Turner Yankton
Tennessee	Blount Claiborne Jefferson Knox	Loudon Monroe Sevier
Texas	Bailey Fannin	
Utah	Box Elder Davis Millard	Sanpete Sevier
Vermont	Franklin	
Washington	Walla Walla	
Wisconsin	Dane Green Rock	

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of the environmental radioactivity data follow for Atomics International, the Feed Materials Production Center, and the Oak Ridge Gaseous Diffusion Plant.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International
July–December 1966[2]

North American Aviation, Inc.
Canoga Park, California

Atomics International, a Division of North American Aviation, Incorporated, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of

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[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1, 1966 to December 31, 1966 and Annual Report 1966," Atomics International, Division of North American Aviation, Inc.

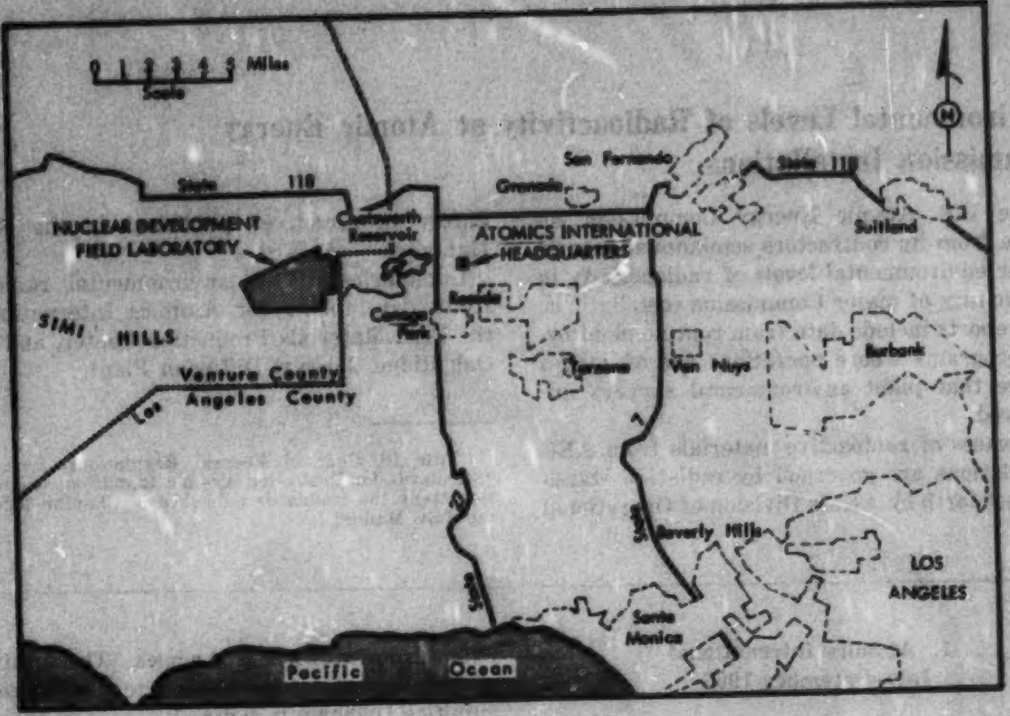
0 1 2 3 4 5 Miles
Scale
San Fernando
State 118
Granada
Sunland
State 118
Chatsworth Reservoir
NUCLEAR DEVELOPMENT FIELD LABORATORY
ATOMICS INTERNATIONAL HEADQUARTERS
Reseda
Canoga Park
SIMI HILLS
Tarzana
Van Nuys
Burbank
Ventura County
Los Angeles County
Beverly Hills
LOS ANGELES
Santa Monica
Pacific
Ocean

Figure 1. Atomics International facilities and vicinity

each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20-cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for the first and the last half of 1966.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics International, 1966

Location	January-June 1966		July-December 1966	
	Number of samples	Average concentration (pCi/m³)	Number of samples	Average concentration (pCi/m³)
Headquarters	380	0.14	848	0.21
NDFL	1,178	.16	1,027	.18

Water monitoring

Process water used at the NDFL is obtained from wells and stored in two 50,000-gallon tanks. Potable water is delivered to the site by a vendor and is not analyzed. Well water is sampled monthly from the supply line at two locations. The average well water radioactivity is presented in table 2.

Table 2. Well water radioactivity, NDFL site Atomics International, 1966

Type of radioactivity	January-June 1966		July-December 1966	
	Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.11	12	0.15
Beta-gamma	12	5.9	12	3.2

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

Table 3. Chatsworth Reservoir water radioactivity Atomics International, 1966

Sample	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	6	0.35	6	0.29
	Beta-gamma	6	6.4	5	5.2
Supply inlet	Alpha	6	.47	6	.35
	Beta-gamma	6	6.9	6	4.8

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NAA Boundary. Samples, obtained and analyzed monthly, include stream-bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Main Holding Reservoir[a] and Bell Creek, Atomics International, July–December 1966

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir Sta. 6[a] (pCi/liter)	5	0.07	5.3
Reservoir Sta. 12[a] (pCi/liter)	6	1.4	6.6
Bell Creek Mud (pCi/g)	3	.39	25
Bell Creek Vegetation (pCi/g ash)	3	1.13	108
Bell Creek Water (pCi/liter)	3	.75	1.3

[a] Locations not shown on figure 3.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top one-half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil Atomics International, 1966

Area	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/g)	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.39	72	0.43
	Beta-gamma	73	31	70	33
Offsite	Alpha	24	.45	24	.43
	Beta-gamma	24	25	24	24

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation Atomics International, 1966

Area	Type of radioactivity	January-June 1966		July-December 1966	
		Number of samples	Average concentration (pCi/g ash)	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.40	72	0.35
	Beta-gamma	72	176	72	162
Offsite	Alpha	24	.39	24	.35
	Beta-gamma	24	130	24	117

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Second half 1965	September 1966
First half 1966	March 1967

2. Feed Materials Production Center
July–December 1966 [3]

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the AEC. The location as related to populated areas is shown in figure 2. Cincinnati and Hamilton—the larger nearby communities—are situated 20 and 10 miles, respectively, from the Center. Operations at this project deal with the processing of high-grade uranium ores and ore concentrates to produce metallic uranium and with fabricating the metal into fuel elements.

During the many involved reactions and processes that lead to the reactor fuels, various liquid and airborne wastes are generated. These wastes contain varying quantities of uranium. Various in-plant methods are used to curtail their release into the environment surrounding the plant. Almost complete removal of the materials is accomplished by using dust collectors and waste treatment processes. In order to determine what concentrations reach the area surrounding the project an environmental survey program has been established which consists of water, soil, and air sampling of the environs and performing those analyses on the samples that are indicative of material released from the plants.

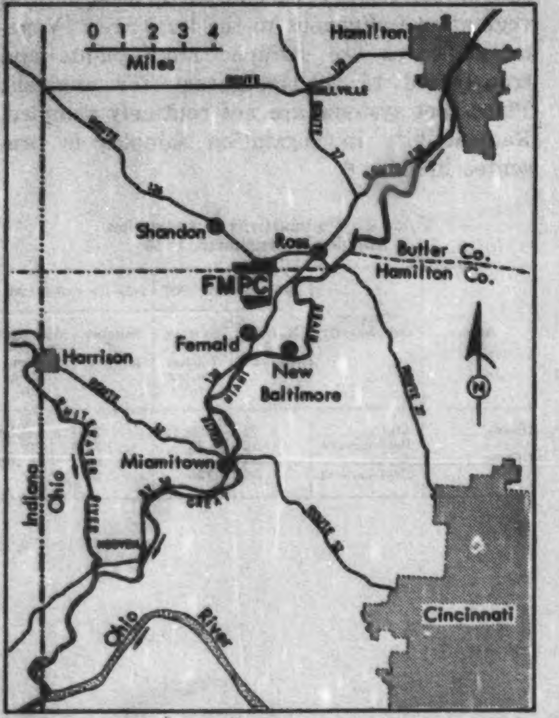
0 1 2 3 4
Miles
Hamilton
Shandon
Ross
Butler Co.
Hamilton Co.
FMPC
Fernald
New Baltimore
Harrison
Miamitown
Indiana
Ohio
Cincinnati
Ohio River

Figure 2. Area map of Feed Materials Production Center

Onsite air samples are obtained from four permanent perimeter air sampling stations, located at the four corners of the production area, shown in figure 3. Samples from these perimeter stations are collected once each week and analyzed for uranium and total radioactivity. Offsite samples are collected by a mobile air sampling unit. The location at which samples are collected is determined by local meteorological conditions on the day of sampling. Approximately 20 percent of all samples are taken upwind of the FMPC plant. Replicate samples are taken at each sampling point and averaged to obtain a representative concentration for that location. Concentrations of uranium and total radioactivity of airborne particulates sampled at onsite and offsite locations are given in table 7.

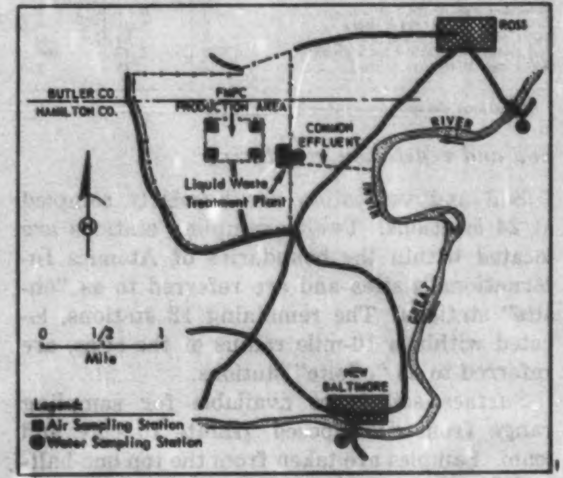
ROSS
BUTLER CO.
HAMILTON CO.
FMPC
PRODUCTION AREA
COMMON
EFFLUENT
Liquid Waste
Treatment Plant
RIVER
MIAMI
GREAT
0
1/2
1
Mile
NEW
BALTIMORE
Legend
Air Sampling Station
Water Sampling Station

Figure 3. Air and water sampling stations, FMPC

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[3] Summarized from "Feed Materials Production Center Environmental Monitoring Semi-Annual Report for the Second Half of 1966, Summary Report for 1966" (NLCO–982).

Table 7. Radioactivity levels of airborne particulates, Feed Materials Production Center, July–December 1966

Location	Number of samples	Uranium concentration (pCi/m³)[a]			Total radioactivity (pCi/m³)[b]		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Onsite:							
Southwest	[illegible]	0.7	<0.1	<0.1	4.2	<0.1	0.5
Northwest	[illegible]	.2	< .1	.1	1.1	< .1	.3
Northeast	[illegible]	1.0	< .1	.1	1.8	< .1	.3
Southeast	[illegible]	.3	< .1	.1	1.1	< .1	.3
All onsite samples	110	1.0	< .1	.1	4.2	< .1	.3
Offsite:							
0-2 miles from FMPC	[illegible]	.7	< .1	< .1	8.0	.1	1.3
2-4 miles from FMPC	[illegible]	.2	< .1	< .1	1.4	< .1	.3
4-8 miles from FMPC	[illegible]	.1	< .1	< .1	.4	< .1	.1
8-12 miles from FMPC	[illegible]	< .1	< .1	< .1	.3	< .1	< .1
All offsite samples	82	.7	< .1	.1	8.0	< .1	.5

[a] AEC radiation protection standard—2 pCi/m³.
[b] AEC radiation protection standard—100 pCi/m³.

Water monitoring

Each of the individual production plants on the project has collection sumps and treatment equipment to remove the uranium from the process waste water. The effluent from the plants is collected at a general sump for equalization and settling. The clear water from the sump is pumped to the river. The solid portion is pumped to a chemical waste pit for further settling. The flow, which is decanted to the clear-well portion of the pit, is virtually free of solids and radioactivity. The effluent from the sump and clear well is combined with waste water from the FMPC water treatment plant, sanitary sewage treatment plant, and storm sewerage system and discharged via a common effluent outfall into the Great Miami River. A weir-type water sampler collects samples of the combined effluent stream, which are removed and analyzed daily. These results are utilized with measurements of river flow in calculating the radioactive contaminant concentrations added to the river. Weekly spot samples are also obtained upstream and downstream from the common FMPC effluent at locations shown in figure 3. The results of the FMPC water monitoring program for July-December 1966 are summarized in table 8.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	October 1966
January–June 1966	April 1967

Table 8. Radioactivity in the Great Miami River, Feed Materials Production Center, July–December 1966

Location	Number of samples	Uranium concentration (pCi/liter)[a]			Total radioactivity (pCi/liter)[b]		
		High	Low	Average	High	Low	Average
Sewer outfall	181	110	<10	2	220	<10	<10
Upstream from outfall	24	40	<10	10	100	<10	30
Downstream from outfall	29	60	<10	13	140	<10	40

[a] AEC radiation protection standard—20,000 pCi/liter.
[b] AEC radiation protection standard—3,000 pCi/liter.

3. Oak Ridge Area
July–December 1966 [4]

Union Carbide, Nuclear Company
Oak Ridge, Tennessee

The Oak Ridge Area is a complex made up primarily of the Y–12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches located in the Conasauga shale formation. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 4) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances of from 12 to 75 miles (figure 5). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average concentrations are presented in tables 9 and 10. Airborne radioactive iodine is monitored in the immediate environment of the plant areas by passing air through a cartridge containing activated charcoal.

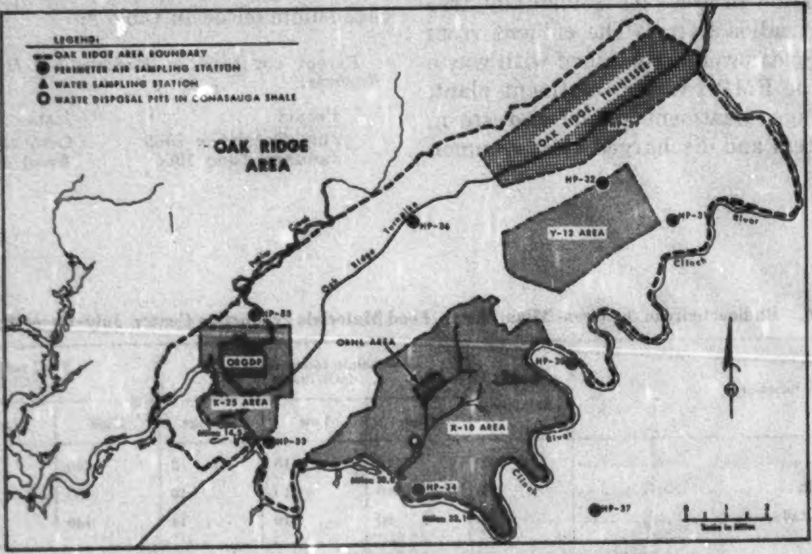
LEGEND:
OAK RIDGE AREA BOUNDARY
● PERIMETER AIR SAMPLING STATION
▲ WATER SAMPLING STATION
○ WASTE DISPOSAL PITS IN CONASAUGA SHALE
OAK RIDGE AREA
OAK RIDGE, TENNESSEE
HP-32
HP-31
River
Y-12 AREA
Clinch
HP-36
Oak Ridge Turnpike
HP-35
ORGDP
K-25 AREA
Miles 14.5
HP-33
ORNL AREA
HP-30
X-10 AREA
River
Clinch
Miles 20.8
HP-34
Miles 22.1
HP-37
Scale in Miles

Figure 4. Oak Ridge area environmental sampling locations

125

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[4] Summarized from "Environmental Levels of Radioactivity for the Oak Ridge Area" (Report Period, July–December 1966). Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

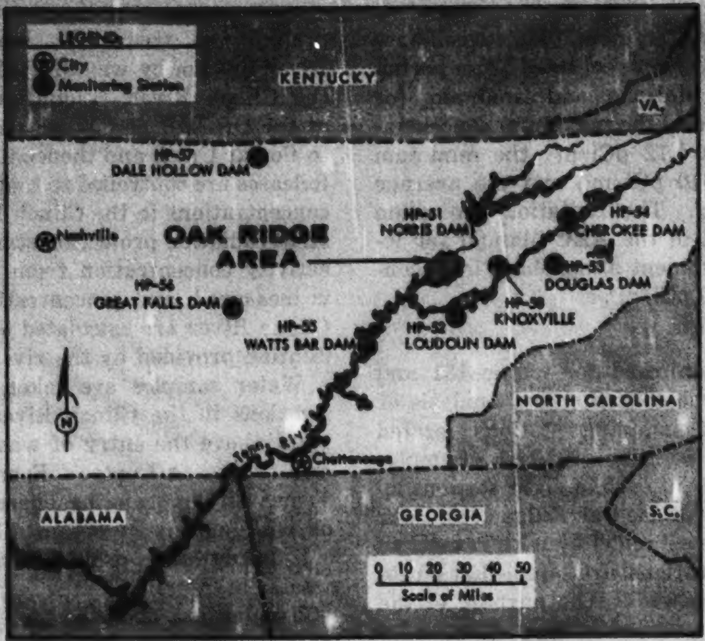
LEGEND
City
Monitoring Station
KENTUCKY
VA.
HP-57
DALE HOLLOW DAM
Nashville
OAK RIDGE AREA
HP-51
NORRIS DAM
HP-54
CHEROKEE DAM
HP-53
DOUGLAS DAM
HP-56
GREAT FALLS DAM
HP-58
KNOXVILLE
HP-52
LOUDOUN DAM
HP-55
WATTS BAR DAM
N
NORTH CAROLINA
Tenn. River
Chattanooga
ALABAMA
GEORGIA
S.C.
0 10 20 30 40 50
Scale of Miles

Figure 5. Remote air monitoring stations, Oak Ridge area

Table 9. Long-lived gross beta radioactivity of particulates in air, Oak Ridge area, July–December 1966

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard ª	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard ª
HP-31	26	0.09	0.09	HP-51	26	0.11	0.11
HP-32	26	.11	.11	HP-52	25	.10	.10
HP-33	26	.08	.08	HP-53	26	.10	.10
HP-34	26	.08	.08	HP-54	26	.09	.09
HP-35	26	.09	.09	HP-55	26	.09	.09
HP-36	182	.14	.14	HP-56	26	.12	.12
HP-37	26	.08	.08	HP-57	26	.09	.09
HP-38	26	.10	.10	HP-58	24	.11	.11
HP-39	26	.11	.11				
Average		0.10	0.10	Average		0.10	0.10

ª The applicable AEC Radiation Protection Standard is 100 pCi/m³.

Table 10. Long-lived gross alpha radioactivity of particulates in air, Oak Ridge area, July–December 1966

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard ª	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard ª
HP-31	26	0.005	0.25	HP-51	26	0.004	0.20
HP-32	26	.007	.35	HP-52	25	.004	.20
HP-33	26	.005	.25	HP-53	26	.003	.15
HP-34	26	.004	.20	HP-54	26	.003	.15
HP-35	26	.008	.40	HP-55	26	.003	.15
HP-36	182	.013	.65	HP-56	26	.003	.15
HP-37	26	.004	.20	HP-57	26	.003	.15
HP-38	26	.003	.15	HP-58	24	.004	.20
HP-39	26	.006	.30				
Average		0.006	0.30	Average		0.003	0.15

ª The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.

During the July–December 1966 surveillance period, 206 samples were collected from perimeter monitoring stations and analyzed for iodine–131. Of these, the maximum concentration detected was 0.12 pCi/m³, the minimum was less than 0.010 pCi/m³, and the average was 0.012 pCi/m³. The radiation protection standard specified in the AEC Manual for iodine–131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m³.

Milk monitoring

Raw milk is monitored for iodine–131 and strontium–90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak Ridge operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine–131 and strontium–90 detected in raw milk samples during the period are given in table 11.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River System by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y–12 plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Table 11. Radionuclides in raw milk, Oak Ridge area July–December 1966

Radionuclide and location	Concentration, pCi/liter		
	Maximum	Minimum [a]	Average
Iodine-131			
Immediate environs	114	<10	8
Remote environs	15	<10	6
Strontium-90			
Immediate environs	53	7	27
Remote environs	40	14	24

[a] The minimum detectable concentrations of iodine-131 and strontium-90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this concentration.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta particle emitters, uranium, and the transuranic alpha-particle emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 12 for the period from July through December 1966.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For both samples, the ura-

Table 12. Concentrations of major radionuclides in the Clinch River, July–December 1966

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River [a]		
	Mile 23.1 [b] (Upstream)	Mile 20.8 [c] (Outfall)	Mile 4.5 (Downstream)
Strontium-90	0.5	0.6	1.3
Cerium-144	0.2	<0.1	0.3
Cesium-137	ND	0.2	1.9
Ruthenium-106	0.1	4.3	2.0
Cobalt-60	ND	0.5	1.3
Zirconium-niobium-95	ND	0.1	ND
Gross beta	0.8	14	6.8

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.

[b] Sampling station moved from Clinch River mile (CRM) 41.5 to Melton Hill Dam CRM 23.1 about January 1, 1966.

[c] The concentrations at mile 20.8 are not measured directly but the values are calculated based on the levels of waste released and the dilution afforded by the river.

ND, non-detectable.

nium concentrations were less than 1 pCi/liter, the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 2×10^4 pCi/liter.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 13 in terms of mR/hr.

Table 12. External gamma radiation levels, Oak Ridge area, July–December 1966 [a]

Location	Average dose rate (mR/hr)
Solway Gate	0.012
Y-12, East Portal	0.011
Newcomb Road	0.012
Gallaher Gate	0.011
White Wing Gate	0.012
Five locations	0.012

[a] The background in the Oak Ridge area determined in 1943 was approximately 0.012 mR/hr.

Discussion of data

The average air contamination levels for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 4 and 5) were 0.10 percent of the AEC radiation protection standard for populations in the neighborhood of a controlled area. These levels are approximately the same as those for the first half of 1966.

The average air contamination levels for gross alpha radioactivity (as shown by the continuous air monitoring filter data) for the immediate and remote environs of the plants were 0.30 percent and 0.15 percent, respectively, of the AEC radiation protection standard for natural uranium for application to populations in the neighborhood of a controlled area.

The average concentration of iodine–131 in air in the immediate environs of the plants was 0.012 pCi/m³. This is approximately 0.012 percent of the AEC radiation standard for populations in the neighborhood of a controlled area.

The average concentrations of iodine–131 in raw milk in the immediate and remote environs of the Oak Ridge area were 8 pCi/liter and 5.9 pCi/liter, respectively. The maximum concentration observed, 114 pCi/liter, occurred on November 9, 1966, approximately 4 days after the arrival in the Oak Ridge area of fallout containing fresh fission products. The average values fall within FRC Range I if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentrations of strontium-90 in raw milk in the immediate and remote environs of the controlled area were 27 pCi/liter and 24 pCi/liter, respectively. These levels fall within FRC Range II for transient rates of daily intake of strontium–90 for application to the average of suitable samples of an exposed population.

The calculated average concentration of gross beta radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at mile 4.5 (near Kingston, Tenn.) were 14 pCi/liter and 6.8 pCi/liter, respectively. These values are 0.63 percent and 0.45 percent of the weighted average AEC radiation protection standards. The average concentration of transuranic alpha particle emitters in the Clinch River at mile 20.8 was 0.10 pCi/liter which is approximately 0.005 percent of the weighted average AEC radiation protection standard.

The average activity of natural uranium materials in the Clinch River, reflecting the effects of all Oak Ridge plants, was less than 0.01 percent of the AEC radiation protection standard for natural uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.012 mR/hr, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	September 1966
January–June 1966	January 1967

SECTION V. TECHNICAL NOTES

Gross Beta Radioactivity in *FUCUS* Hybrids (Rockweed) From the Niantic Estuary, Connecticut, 1961-1964[1]

Thomas W. Hatfield, Donald M. Skauen, and *Nelson Marshall*[2]

A study of gross beta radioactivity in various species of biota of the upper Niantic estuary was conducted from the fall of 1961 through the fall of 1962. A nuclear power plant is being constructed at Millstone Point, Waterford, Conn., which is in the Niantic Bay area. These studies represent a part of various studies on baseline radioactivity in the area.

Gross beta radioactivity was measured at approximately monthly intervals in a variety of marine organisms collected where they are relatively abundant along the axis of the Niantic estuary in Connecticut and from adjacent waters of Long Island Sound (figure 1). The collections included specimens of sea lettuce, rockweed, kelp, eelgrass (*Zostera*), two species of mussel, scallop, oyster, and both the hard-shell and soft-shell clams.

Except for two results of 1,042 and 572 pCi/g of ash for specimens of the hard-shell and soft-shell clams, respectively, collected November 21, 1961, none of the mollusks showed radioactivity in excess of 400 pCi/g ash. Except for the rockweed *Fucus*, none of the plants showed radioactivity in excess of 800 pCi/g ash. However, *Fucus*—particularly in samples taken near the headwaters of the Niantic estuary—showed high gross beta radioactivity levels during the winter of 1961–1962. The gross beta radioactivity level in *Fucus* also exceeded the

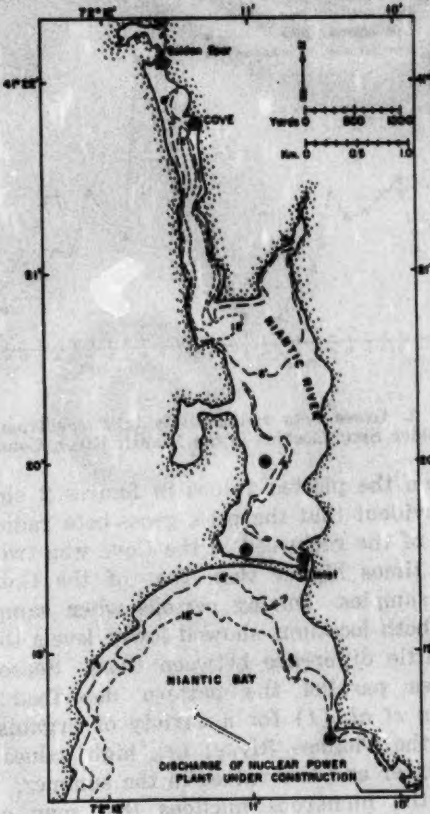

Figure 1. Niantic estuary, showing location of the Golden Spur, Cove, and other stations

highs found in a wide variety of marine organisms taken from other locales in a broad program of monitoring along the southeastern New England shoreline (Skauen *et al.* (*1*), and Hatfield, unpublished data). Their monitoring included many samples of *Fucus* but none from the upper reaches of any other estuary.

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[1] This study was supported in part by Research Grant RH-73 from the Department of Health, Education, and Welfare with the University of Connecticut, and in part by the Atomic Energy Commission under contract AT(30-1)-2678 with the University of Rhode Island.

[2] Professor Hatfield is chairman of Life Sciences, Mitchell College, New London, Conn.; Professor Skauen is professor of Pharmacy, University of Connecticut, Storrs, Conn.; and Professor Marshall is professor of Oceanography, University of Rhode Island, Kingston, R.I.

To follow the gross beta radioactivity levels in *Fucus* in the upper Niantic estuary, sampling of rockweed was extended through January 1964 from the Golden Spur and Cove stations, where growths were abundant on rocks and small boulders in the intertidal zone. The results for the Golden Spur and Cove sampling areas are shown graphically in figures 2 and 3. The *Fucus* collected is considered to consist of an intertidal hybridizing mixture of *F. vesiculosis* and *F. spiralis* (*2*).

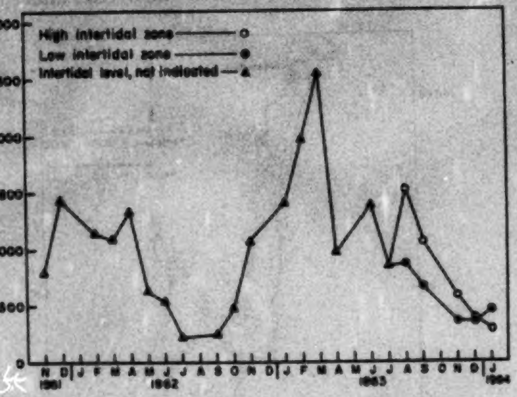

Figure 2. Gross beta radioactivity in *Fucus* from the Golden Spur location in the Niantic River, Conn.

From the plotted values in figures 2 and 3 it is evident that the peak gross-beta radioactivity of the rockweed in the Cove was two or three times higher than that of the Golden Spur samples. During periods when samples from both locations showed lower levels there was little difference between them. Seasonal changes parallel the pattern described by Skauen *et al.* (*1*) for a variety of organisms from the Thames River; *i.e.*, high values in the winter and low values in the summer.

Of the numerous nuclides that may contribute to this radioactivity, one—ruthenium—was ascertained by chemical separation by the method described by Boni (*3*) for radionuclides in environmental samples. The analysis indicated that about 6 percent of the observed gross beta radioactivity can be attributed to ruthenium–103 and –106 and, though the percentage is small, it provides a clue to the sources and routes of contamination. In their review, Auerbach and Olson (*4*) indicate that very little is known about the movement of ruthenium through the environment, particularly the marine environment, although from the work of Tsuruga (*5*), it is known that some seaweeds may concentrate ruthenium. In the Niantic area it is difficult to conceive of a source of radioactive ruthenium other than from fallout. The high values in the upper Niantic estuary suggest that fallout is carried to the headwaters via watershed drainage. There is no apparent explanation for the higher levels of gross beta radioactivity in the Cove samples as compared with the Golden Spur samples, which are closer to the headwaters. Possibly factors such as undetermined hydrologic variation or differences in growth rates of the rockweed at the two locations play a role.

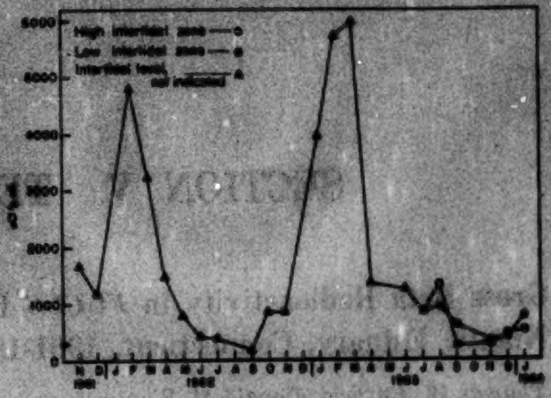

Figure 3. Gross beta radioactivity in *Fucus* from the Cove location in the Niantic River, Conn.

Relative to the environmental and uptake routes, the following seem pertinent:

1. The fluctuations in *Fucus* (figures 2 and 3) seem to follow by a few months changes in levels of gross beta radioactivity in the air at the Hartford-Providence stations (*6*) (figure 4). This relationship is not so obvious with respect to the total beta radioactivity in the precipitation at these two stations.

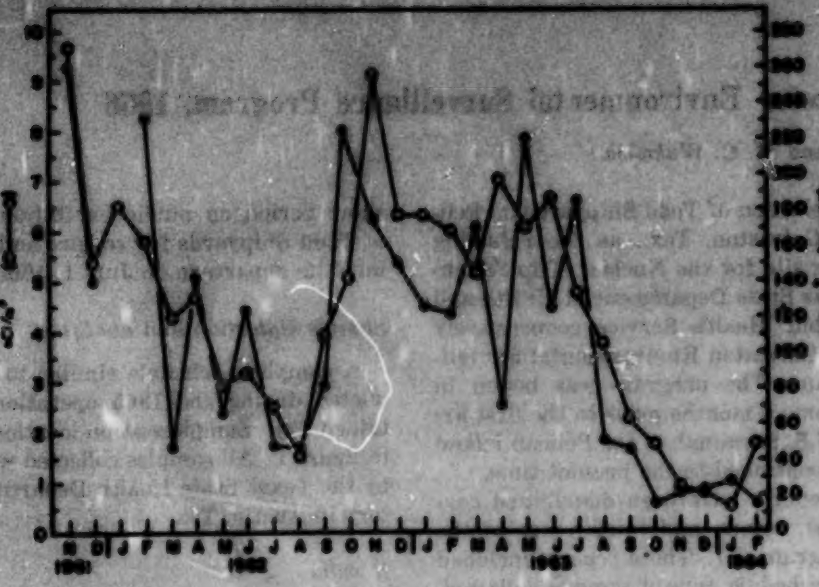

Figure 4. Gross beta radioactivity in air samples (left ordinate) and in precipitation (right ordinate). Averages for Hartford, Conn., and Providence, R.I., sampling stations

2. The highest results observed for *Fucus* occur during the time of greatest river discharge.

3. Gross beta radioactivity in *Fucus* samples shows seasonal variations. The few collections in which samples from high in the intertidal zone were compared with samples low in the intertidal zone suggest that there may be differences relating to elevation.

Noting the relationship of peak gross beta radioactivity in the air early in the winter, followed by peak gross beta radioactivity in *Fucus* at the time of maximum late winter river discharge, one may speculate that the gross beta radioactivity in the air accumulates in the watershed and runs off with late winter thaws and melting.

The foregoing preliminary findings suggest that extension of our studies on *Fucus* may provide a useful means of monitoring environmental releases of radioactivity.

REFERENCES

(*1*) SKAUEN, D. M., T. HATFIELD, D. HANLON, and J. S. RANKIN, Jr. Gross beta activity in the Thames River (Connecticut). Nature 191:1017 (1961).

(*2*) CONOVER, J. T. Personal communication.

(*3*) BONI, A. L. Quantitative analysis of radionuclides in process and environmental samples. Anal Chem 32:599–604 (1960).

(*4*) AUERBACH, S. I., and J. S. OLSON. Biological and Environmental Behavior of Ruthenium and Rhodium. Radioecology:509–519. Rheinhold Publishing Corporation, New York, N.Y., and American Institute of Biological Sciences, Washington, D.C. (1963).

(*5*) TSURUGA, H. The uptake of radioruthenium by several kinds of littoral seaweeds. Bull Japanese Soc Scientific Fisheries 28:1149–1154 (1962).

(*6*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radiation Surveillance Network. Radiol Health Data 3 (February 1962) through 5 (May 1964). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The Galveston Environmental Surveillance Program, 1966

R. Stewart and M. C. Wukasch [1]

With the selection of Todd Shipyards on Pelican Island, Galveston, Tex., as the refueling and servicing site for the Nuclear Ship Savannah, the Texas State Department of Health and the U.S. Public Health Service cooperatively initiated the Galveston Environmental Surveillance Program. The program was begun in June 1962, some 6 months prior to the first arrival of the N.S. Savannah at the Pelican Island site and has continued to the present time.

Previous reports have been distributed covering the first, second and third years of the sampling program (*1*). These reports included the sampling schedule, type of samples collected, location of sampling stations, and results of the analyses of samples collected during that time. This report is for the purpose of providing essentially the same information for that portion of 1966 when the N.S. Savannah was in Galveston Harbor. The N.S. Savannah arrived in Galveston Harbor June 1, 1966, and after a short period on public exhibition was docked at Todd Shipyards for repairs and modification until its departure on July 1, 1966.

Sample collection and analyses

A sampling schedule similar to the one conducted during the 1965 operation was maintained (*2*). Sample station locations are shown in figure 1. All samples collected were analyzed by the Texas State Health Department Laboratory in Austin, Tex.

Results

The analytical results of environmental samples collected in the Galveston vicinity are presented herein.

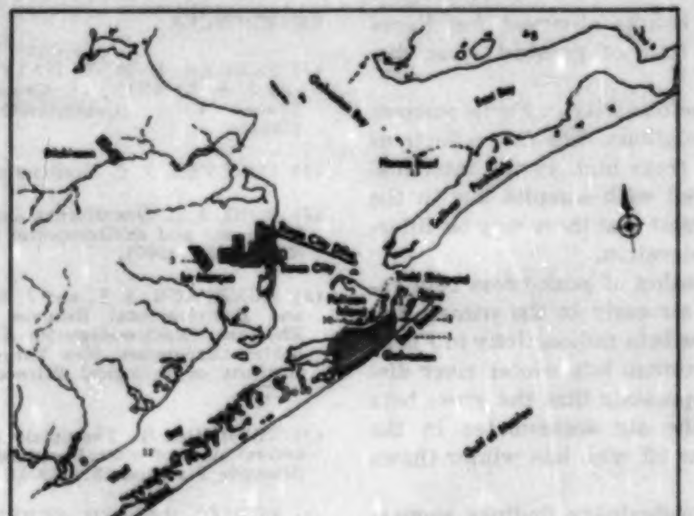

Figure 1. Galveston sampling locations

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[1] Mr. Stewart is supervisor, Surveillance Activities Radiation Control Program and Mr. Wukasch is chief, Radiation Control Program, Division of Occupational Health and Radiation Control, Texas State Department of Health, Austin, Tex.

Air radioactivity

Air samples were collected with a high-volume sampler located on the roof of the Galveston City Hall. Gross beta radioactivity in these air samples is listed in table 1.

Wide fluctuations of gross beta radioactivity in air occurred during the first year's operations as reported in the previous report (*2*). Lesser variations were detected during the present sampling period. The increase noted during May and June 1966 is attributed to fallout resulting from the May 9, 1966 atmospheric nuclear test conducted by mainland China. Similar increases in radionuclide contamination were observed in milk samples collected during this time period.

Table 1. Radioactivity in air, Galveston City Hall Station No. 1

Date filter removed (1966)	Gross beta radioactivity (pCi/m³)
May 27	0.4
31	1.0
June 1	.6
3	.7
6	.4
8	NS
10	.9
13	.7
15	.3
20	.2
22	.3
24	.3
27	.3
29	.3
July 1	.3
6	.2
8	NS
11	.2

NS, no sample.

Milk radioactivity

The concentration of various radionuclides in the raw milk samples is listed in table 2. The detection of the short half-lived isotopes (iodine–131 and barium–140) as indicative of the presence of fresh fission products. Similar detections were noted throughout the entire United States during this time period as a result of the mainland Chinese test mentioned previously.

Table 2. Radionuclide concentrations in milk, Station No. 29

Date collected (1966)	Iodine-131 (pCi/liter)	Barium-140 (pCi/liter)	Cesium-137 (pCi/liter)	Strontium-90 (pCi/liter)
May 18	ᵃ <10	ᵃ <10	45	9
25	10	5	30	8
June 1	20	10	45	13
8	10	10	40	11
15	10	ᵃ <10	35	11
22	10	ᵃ <10	30	10
29	10	ᵃ <10	30	11
July 6	10	ᵃ <10	30	11
11	10	ᵃ <10	30	10

ᵃ Minimum detectable level is 10 pCi/liter (2 σ analytical error).

Sea water radioactivity

The high dissolved solids content of sea water makes the standard gross beta and gross alpha radioactivity determinations impractical from an analytical standpoint. Chemical fractionation of samples has therefore been necessary. The carbonate and basic sulfides fractions have been used in this study as indicators of sea water contamination. The radioactivity of the carbonate fraction is indicative of alkaline earths content. Strontium and radium are part of this chemical family. The radioactivity of the basic sulfides fraction is indicative of the transitional elements (*e.g.*, cobalt, zinc, iron, and nickel) and the rare earths (*e.g.*, cerium, yttrium, ruthenium, and zirconium). Interference because of sodium solids and potassium–40 radioactivity is eliminated by these two chemical fractionations.

Sea water samples were collected from two locations during this report period. Results of the analyses are given in tables 3 and 4. There was little change in the levels of radionuclide contamination found during the periods of the previous reports. The highest concentration in the carbonate fraction was 4 pCi/liter and in the basic sulfides fraction, 19 pCi/liter. These low levels can be attributed to natural background variations.

Radioactivity in silt

Silt samples were collected from the bottom of Galveston Channel at Station No. 11 (table 5), four times during the report period by means of a spring activated, hand operated silt dredge. The samples were collected prior to the arrival of the N. S. Savannah, during its visit and following its departure from the channel.

Summary

As the result of the 1966 operation of the Galveston Environmental Surveillance Program, it has been shown that no detectable ra-

Table 3. Radioactivity in sea water, Station No. 10

Date collected (1966)	Suspended solids		Dissolved solids				Gamma-ray scan (pCi/liter)
	Gross alpha radioactivity (pCi/liter)	Gross beta radioactivity (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)		
			C[a]	BS[b]	C[a]	BS[b]	
May 19	3	4	(c)	(c)	4	1	(d)
26	1	4	<1	(c)	(c)	3	(d)
June 1	NS	NS	NS	NS	NS	NS	(d)
8	1	1	<1	1	1	2	(d)
15	<1	1	<1	(c)	3	2	(d)
21	(c)	<1	(c)	9	1	2	(d)
29	<1	3	(c)	1	3	2	(d)
July 5	40	38	(c)	(c)	<1	3	(d)
11	<1	3	(c)	<1	3	1	(d)

[a] C, carbonate fraction.
[b] BS, basic sulfides fraction.
[c] Not significantly greater than background.
[d] No significant peaks other than potassium-40.
NS, no sample.

Table 4. Radioactivity in sea water, Station No. 11

Date collected (1966)	Suspended solids		Dissolved solids				Gamma-ray scan (pCi/liter)
	Gross alpha radioactivity (pCi/liter)	Gross beta radioactivity (pCi/liter)	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)		
			C[a]	BS[b]	C[a]	BS[b]	
May 19	<1	1	<1	(c)	1	10	(d)
26	3	3	(c)	19	(c)	1	(d)
June 1	1	1	1	1	2	2	(d)
8	(c)	1	(c)	(c)	1	2	(d)
15	(c)	1	(c)	13	1	8	(d)
21	(c)	1	(c)	(c)	1	1	(d)
29	26	23	(c)	11	1	7	(d)
July 5	(c)	2	(c)	1	1	1	(d)
11	(c)	1	(c)	(c)	2	(c)	(d)

[a] C, carbonate fraction.
[b] BS, basic sulfides fraction.
[c] Not significantly greater than background.
[d] No significant peaks other than potassium-40.
NS, no sample.

Table 5. Radioactivity in silt, Station No. 11

Date collected (1966)	Gross alpha radioactivity (pCi/kg)	Gross beta radioactivity (pCi/kg)	Gamma-ray scan (pCi/kg)
May 19	1.46×10^3	7.78×10^3	(a)
June 8	2.07×10^3	9.82×10^3	(a)
July 5	1.84×10^3	9.33×10^3	(a)
July 11	2.52×10^3	8.91×10^3	(a)

[a] No significant peaks other than potassium-40.

dioactive contamination occurred in the Galveston-Pelican Island area because of the operations of the N. S. Savannah. The low levels of radioactivity detected in the various environmental samples are attributed to naturally occurring radionuclides and mixed fission products resulting from the testing of nuclear weapons.

The results reported herein are almost entirely free of large fluctuations. The variations noted may all be attributed to the atmospheric test conducted on mainland China on May 9, 1966. With the exception of the milk samples, almost all the results are shown to be below or just above the detection limit. As was mentioned previously, the milk radioactivity trends followed closely the nationwide trend as reported by the U.S. Public Health Service.

REFERENCES

(1) TEXAS STATE DEPARTMENT OF HEALTH. Interim reports of operations 1963, 1964, and 1965. Texas State Department of Health, Austin, Tex.

(2) FLORA, D. H. and M. C. WUKASCH. The Galveston environmental surveillance program, 1965. Radiol Health Data Rep 7:263–267 (May 1966).

Radioactive Material Handling Problems in Oil and Gas Well Logging

J. H. Fontaine[1] and *D. H. Flora*[2]

Radioactive material has been used in oil and gas well logging since the late 1930's, but only during the last 5 to 10 years has expanded use of the technology become employed (*1*). The specific uses of radioactive material in well logging and its associated health physics problems have only recently achieved special attention by various State regulatory agencies and by the health physics profession as a whole (*2*). This note reviews some of the problems associated with the oil and gas well logging industry as observed in Texas. It is felt the experience in Texas is analogous to that of other States in which oil and gas drilling is actively being pursued.

The oil well drilling and servicing industries in Texas employ nearly 44,000 workers out of a total of 201,800 in the petroleum and petrochemical industry. While some oil-producing zones are located in densely populated areas within the State, the large majority of drilling has occurred in sparsely populated areas.

Radioisotopes are used in various ways to obtain information useful to the geologist in developing productive reservoirs of oil or natural gas, and in drilling and completing wells. As tracers, radionuclides permit the engineer to follow the movement of liquids or gases within a well bore or through the reservoir. By adding tracers to various materials emplaced in the well bore, one can determine the exact location of reservoirs. The use of sealed gamma-ray sources permits measuring the density of gaseous, liquid and solid materials within or surrounding the well bore. Sealed gamma-ray sources are also used as orienting devices in depth control and perforating. The beryllium (α, n) reaction produces neutrons which may be used in several ways. Bombarding a tritium target with deuterons produces an even more intense source of high energy neutrons. This technique has come to the forefront in the well logging industry by development and use of "down-hole" neutron generators.

Since March 1, 1963, when Texas became an agreement State, 63 radioactive material licenses have been issued, authorizing over 300 individuals to use radioisotopes in oil and gas well logging. This represents 7.0 percent of the total number of licenses issued. Careless handling methods and hazardous operations evolved from the widespread use of radium in the well logging industry and lack of previous government regulations concerning its use.

Probably the greatest radiation hazard in well logging is source handling. Direct source manipulation has been observed, despite the fact that proper handling tools have been devised which reduce radiation exposure to a minimum. These handling tools come in assorted sizes and shapes but their purpose is the same; namely, to reduce radiation exposure by the distance technique. Also, the use of plutonium-beryllium and americium-beryllium neutron sources rather than the older radium-beryllium source has become widespread throughout the industry to reduce high gamma-ray levels.

Proper storage of radioactive materials, whether at the company's factilities or on the logging truck, is another problem area in the well logging industry. Standard lead containers have been used incorrectly to store neutron sources, and paraffin shields have been [illegible] incorrectly to store large gamma-ray sources. Transporting containers with inadequate shielding have been frequently used with regard to radium-beryllium neutron sources. Very high exposure rates have been [illegible]rded in the proximity of logging trucks transporting radium-beryllium sources.

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The use of radioactive material as tracers in well logging also presents some rather unique health physics problems. Since most radioisotopes used as tracers have a relatively short half-life, the main problem is one of personnel protection. Some of the prevalent isotopes used are iodine–131, iridium–192, scandium–46 and zirconium-niobium–95. Most companies have good safety procedures for the use of tracer material, but spills and contamination have been reported. The proper use of impermeable gloves, handling tongs, respirators and in some cases protective clothing can prevent personnel contamination. Contaminating underground potable water reservoirs is almost an impossibility as all oil and gas wells drilled in Texas are required to be cased through freshwater aquifiers. Most injected tracer material is designed to be permanently retained in the well bore or permeable formation of interest. However, material that does inadvertently come back to the surface may be diluted to acceptable limits in above ground drilling fluid reservoirs.

A comparison of the regulatory items of noncompliance found at oil and gas field licensees with industrial radiographers is presented in table 1. This comparison was chosen because of the close correlation between the work environment for the two industries. Both of these industrial operations are usually done in the "field," and the equipment would be subjected to much rougher treatment than would the majority of other users for radioactive materials. It is interesting to note that the percentage of times that they failed to maintain required records is identical in both industries. However, it has been found in Texas that the users of radioactive material associated with oil and gas fields are more delinquent in posting the required signs, labels, etc., than are the radiographers. The reverse situation occurs in operational procedures. This category covers not only the use of improper procedures, but also failure to perform required procedures as outlined in the Texas State Regulations for Control of Radiation (*3*). It should be pointed out here, that these regulations are generally identical and in all cases compatible with similar regulations enforced by the Atomic Energy Commission.

Table 1. Distribution of regulation violations for radioactive materials in oil and gas field licensees and industrial radiographers

Occupational type	Number of inspections [a]	Regulation violation		
		Posting requirements (percent)	Incorrect procedures (percent)	Recordkeeping (percent)
Oil and gas field licensees	94	48	42	10
Industrial radiographers	81	41	40	10

[a] The number of violations per inspection may have been more than one.

Table 2 shows the percentage of legally defined incidents by user category. Legally defined incidents may be summarized as: (1) incidents involving exposures to personnel, releases of radioactive material and property damage at levels which require immediate or 24-hour notification of the Texas Radiation Control Agency; (2) loss or theft of radioactive sources; (3) overexposures of individuals in excess of the regulations; and (4) levels of radiation or concentrations of radioactive materials in unrestricted areas in excess of the regulations. Sixty-seven percent of the 124 incidents summarized in this review occurred in industry and 37 percent of the industrial incidents occurred in the oil and gas well logging industry. Medical users accounted for 21 percent, while educational institutions showed the fewest number of incidents, with around 10 percent.

Table 2. Legally defined incidents reported

Occupational type	Number of incidents	Type of incident		
		Leaking sources or spills (percent)	Lost (percent)	Overexposure (percent)
All users [a]	124	35	35	30
Oil and gas field industry	46	39.1	56.5	4.4

[a] Includes medical, educational, and institutional users, as well as oil and gas well logging.

Improvement in well logging radiation safety is reliant on proper training. Courses in radiation fundamentals and radiological health practices are presented by the U.S. Public Health Service in cooperation with the Texas State Department of Health, as well as the various service companies which provide radioisotopes to the well loggers. In addition, training of users during routine inspections has been performed by State inspectors, particularly in the use and associated hazards of neutrons. This training can be augmented by periodic company safety meetings which emphasize proper operational procedures.

REFERENCES

(1) ARMSTRONG, F. E., and W. D. HOWELL. Recent advances in radioisotope applications for exploitation of petroleum and natural gas reservoirs. Isotopes Rad Technol 3:103–114 (winter 1965–1966).

(2) GEIGER, N. and R. T. MOORE. Radiological health aspects of oil well logging. Public Health Rep 81:1064–1070 (December 1966).

(3) TEXAS STATE DEPARTMENT OF HEALTH, DIVISION OF OCCUPATIONAL HEALTH. Texas Regulations for Control of Radiation, amended June 14, 1965, Texas Radiation Control Act, Article 4590f, Revised Civil Statutes, State of Texas. Texas State Department of Health, Division of Occupational Health, 1100 West 49th Street, Austin, Tex. 78756.

(4) U.S. DEPARTMENT OF THE INTERIOR. Petroleum Production Drilling and Leasing on the Outer Continental Shelf, A Summary. (May 1966).

Reported Nuclear Detonations, July 1967

The U.S. Atomic Energy Commission announced one underground nuclear test conducted at its Nevada Test Site during July 1967. The test of July 27 was a low-intermediate yield test (20 to 20 kilotons TNT equivalent).

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

STRONTIUM-90 IN HUMAN BONES, 1964–1965. *R. M. Hallisey* and *M. A. WALL. Radiological Health Data and Reports, Vol. 8, August 1967, pp. 415.*

Results obtained from analysis of strontium-90 in human bone specimens from 303 individuals who died in 1964 and 293 individuals who died in 1965 have been studied. The bone specimens were collected at autopsies in selected metropolitan cities throughout the United States. A summary table of all the data for deaths occurring in 1964 and 1965 is presented. In most of the five age groups in 1965, average values are slightly lower than the 1964 values. Regional variations in the strontium-90 to calcium ratio are shown with the highest average for each year in the Delta region. The data were related to human bone concentrations that were derived from the Federal Radiation Council's Radiation Protection Guides and intake ranges, and it was shown that in both years the average bone concentrations corresponded to Range I of these intake guides.

KEY WORDS: age groups, Federal Radiation Council ranges, geographical distribution, human bone specimens, strontium-90/calcium ratios, strontium-90.

UPTAKE OF CESIUM-137 FROM CONTAMINATED SOIL BY SELECTED GRASS CROPS. *H. L. Cromroy, W. A. Goldsmith, C. R. Phillips,* and *W. P. Bonner. Radiological Health Data and Reports, Vol. 8, August 1967, pp. 421.*

The cesium-137 content of milk in the Tampa, Fla. area has been consistently above the national average in recent years. The possibility that grasses grown in this area receive their contamination indirectly through contaminated soil is being investigated. Among the grasses investigated in the uptake of cesium-137 appears to be greatest for pangola grass.

KEY WORDS: Bahia grass, cesium-137, contaminated soil, dairy feed, milk, Pangola grass, soil, uptake.

☆ U.S. Government Printing Office: 1967—302799

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 8, Number 9, September 1967

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

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Reports

A Proposed Radioactivity Concentration Guide for Shellfish

C. L. Weaver [1]

The recommendations of the International Commission on Radiological Protection (ICRP), the National Committee on Radiation Protection (NCRP), and the Federal Radiation Council (FRC), have been applied in deriving proposed guides for radioactivity in shellfish. FRC Report No. 1 presents basic exposure criteria, FRC Report No. 2 presents intake guides for strontium–89, strontium–90, iodine–131, and radium–226, and NCRP and ICRP provide data on the maximum permissible concentrations of radionuclides in water. The proposed guide was assembled by the National Center for Radiological Health in collaboration with the Water Supply and Sea Resources Program of the National Center for Urban and Industrial Health, Public Health Service.

Radioactive wastes entering the water environment constitute a potential hazard to humans through consumption of shellfish which have taken up the radioactive material from the water (1–4). Potential sources of such materials are the liquid waste discharges from nuclear power plants, users of radionoclides, and from nuclear-powered ships (*5*). Radioactive wastes from these sources may be discharged into shellfish waters at concentrations not exceeding the applicable standards (Title 10, Part 20, Table II, Appendix B, of the Code of Federal Regulations or comparable State regulations) (*6*). However, due to the accumulation of radionuclides in aquatic food chains, it is possible for certain radionuclides to be present in edible portions of shellfish in quantities sufficient to be of public health concern, even though the concentrations of the radionuclides in water are within permissible limits according to applicable standards. In particular, bivalves have the capacity to concentrate radionuclides to several orders of magnitude above the water concentration. This is due, in part to their use of plankton as a food source.

Concentration factors

Shellfish have the ability, alone or by means of their aquatic food sources, to concentrate certain stable elements and radionuclides far above the ambient concentration in a saline water environment. The term "concentration factor" is commonly used to describe this process quantitatively and is defined as the ratio of the equilibrium quantity of a specific nuclide per unit wet weight of shellfish tissue to the quantity of the specific nuclide per unit weight of water.

The value of these factors vary with shellfish species, rate of metabolism, rate of developmental growth and concentration of the stable isotope of the element of concern in the receiving water. In some cases, the value varies with the concentration of the elements in the same chemical group as the element of concern. Other possible factors such as variations in the specific capacity of aquatic species in a food chain to accumulate radionuclides from host food, lead to fluctuation. Since all of the metabolic factors are temperature dependent, the concentration factor for a particular body of water could vary seasonally.

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Considerations in deriving the radiological guide

The radioactivity guide for shellfish is based on the reports and recommendations of the International Commission on Radiological Protection (ICRP), the National Committee on Radiation Protection (NCRP), and the Federal Radiation Council (FRC) (*7–9*). However, it is necessary to translate their recommendations into specific numerical guides for use in evaluating the public health aspects of radioactive waste disposal practices. NBS Handbook 69(*10*) includes recommendations for the maximum permissible concentration of radioactivity in water $(MPC)_w$, expressed as microcuries-per-cubic centimeter (μCi/cc), for occupational exposure based on a 168-hour week. The intent of these $(MPC)_w$ values is to limit the daily intake of radionuclides which are assumed present in the 2,200 ml volume of water and the food consumed each day by a "standard man." (The maximum permissible daily intake for an occupational worker can be calculated by multiplying the $(MPC)_w$ by 2,200 ml). However, the daily intake for occupational workers must be adjusted so that it applies to the average member of the general public. In this regard, the ICRP recommends that a factor of one-thirtieth be used. Table 1, column 3, gives the (MPC) values for selected radionuclides for members of the general public. Table 1, column 4, gives the maximum permissible intake for the selected radionuclides, in μCi/day, derived on the above basis. In the cases of strontium–90 and iodine–131, the values in column 4 are those recommended by the Federal Radiation Council for the average of an exposed population group.

Selection of NBS Handbook 69 as the basic reference is based on the following statement from the Public Health Service Drinking Water Standards (*11*).

> "In assessing the hazard of radionuclides for which limits have not been provided by the Federal Radiation Council, it is suggested that the values $(MPC)_w$ for the 168-hour week, in table 1, of the report of the International Commission on Radiological Protection (*9*) or the National Committee on Radiation Protection (*10*), adjusted by a factor appropriate for exposure of the general population (1/30), be used. When mixtures of radionuclides are present, the permissible concentration of any single nuclide must be reduced by an amount determined through applicable calculations in these reports."

Guide for radioactivity concentrations in shellfish

The recommended guide for radioactivity concentration in shellfish is based on an assumed consumption rate of 50 grams (wet weight) of shellfish per day. Cowser and Snyder (*12*) report an annual fish consumption

Table 1. Radioactivity concentration guide for shellfish

1	2	3	4	5
Selected radionuclide	Concentration factor [a]	Maximum permissible concentration $(MPC)_w$ [b] (μCi/cc)	Maximum permissible radioactivity intake (μCi/day)	Radiological guide for radioactivity in shellfish (assuming a 50 g day wet weight intake) [d] (μCi/g)
Cromium-51	1,000-100,000	6.67×10^{-4}	1.47	3×10^{-2}
Manganese-54	5,000- 50,000	3.33×10^{-5}	7.33×10^{-2}	1×10^{-3}
Cobalt-58	1,000- 10,000	3.33×10^{-5}	7.33×10^{-2}	1×10^{-3}
Iron-59	3,000- 20,000	2.00×10^{-5}	4.40×10^{-2}	9×10^{-4}
Cobalt-60	1,000- 10,000	1.67×10^{-5}	3.67×10^{-2}	7×10^{-4}
Copper-64	5,000- 50,000	1.00×10^{-4}	2.20×10^{-1}	4×10^{-3}
Zinc-65	1,000- 10,000	3.33×10^{-5}	7.33×10^{-2}	1×10^{-3} Total body
Strontium-90	1-10	(c)	[c] 2.00×10^{-4}	4×10^{-6} Bone
Zirconium-95	1,000- 2,000	2.00×10^{-5}	4.40×10^{-2}	9×10^{-4}
Ruthenium-103	5,000- 50,000	2.67×10^{-5}	5.87×10^{-2}	1×10^{-3}
Ruthenium-106	5,000- 50,000	3.33×10^{-6}	7.33×10^{-3}	1×10^{-4}
Iodine-131	100- 10,000	(c)	[c] 1.00×10^{-4}	2×10^{-6} Thyroid
Cerium-144	1,000- 10,000	3.33×10^{-6}	7.33×10^{-3}	1×10^{-4}

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[a] These concentration factors were not used in deriving the guides but are presented as one of the considerations for selection of the radionuclides in the first column.

[b] $(MPC)_w$ for 168-hour week multiplied by a factor of 1/30 for exposure of the general population.

[c] Based on the recommendations of the Federal Radiation Council for an average of suitable samples of an exposed population group. The μCi/g values have been rounded to the nearest whole number. Radionuclide

[d] The critical organ is the gastrointestinal tract except as indicated.
concentration in shellfish can be compared with this guide only if they are reported as μCi/g. wet weight.

rate of 37 lb. (approximately 50 g/day) by commercial fishermen. Use of 50 g/day in deriving the shellfish guides is conservative in that it assumes all of the 50 grams consumed are shellfish and that the diet of the general population is similar to the diet of the commercial fisherman. In deriving the values listed in column 5, table 1, it is further assumed that the total radioactivity intake, including drinking water, results from shellfish consumption.

The values given in the guide for radioactivity in shellfish (table 1, column 5) were derived so that the product of assumed shellfish intake (50 g/day, wet weight) times these values (column 5) are equal to the values shown for the maximum permissible daily radioactivity intake (column 4). Thus the values shown in column 4 divided by 50 g/day gives the guide for radioactivity in shellfish (column 5). These values may be adjusted to conform to a known shellfish consumption of greater or less than the 50 g/day used in deriving the guide. The manner in which this guide should be used will depend upon whether there exists significant sources of radionuclide ingestion other than shellfish. Where other sources exist these guide values must, of necessity, be lowered.

The application of this guide requires the examination of radioactivity in shellfish by radiological surveillance techniques such as found in references (*13*) and (*14*). The radionuclides of public health significance which may be found in shellfish include the following:

A. Fission products which include radioisotopes of zirconium, ruthenium, iodine, cerium, and strontium.
B. Activation products, which include radioisotopes of chromium, manganese, iron, cobalt, copper, and zinc.

Table 1 presents a list of selected controlling radionuclides and the recommended guide for radioactivity in shellfish for an assumed intake of 50 grams per day. If the concentration of any single nuclide in shellfish reaches the recommended guide value, the shellfish should not be released for public consumption until after a comprehensive evaluation of the dose to the exposed population from all environmental sources shows that the FRC's Radiation Protection Guides will not be exceeded.

Evaluation of total intake of radioactivity

Analysis of shellfish for radionuclide content will provide data on the concentration of specific nuclides. If more than a single radionuclide is present in the total diet or by inhalation in significant amounts, the evaluation of the sample in terms of this guide should be modified. Assuming the radionuclides are exclusively derived from shellfish and if radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C and if the applicable radiological guides for the radionuclides are as shown in table 1, column 5, then the concentration in the mixture shall be considered to be within the shellfish radioactivity guide as shown in the following relationship:

$$\frac{C_A}{\text{Guide A}}+\frac{C_B}{\text{Guide B}}+\frac{C_C}{\text{Guide C}}=<1$$

The application of this guide may be illustrated by the following example using typical concentrations of radioactivity found in shellfish:

Radionuclide	Concentration in pCi/g
Zirconium-95	0.1
Zinc-65	75.0
Ruthenium-106	1.0

The computation can then be made as follows:

$$\frac{0.1}{900}+\frac{75.0}{1000}+\frac{1.0}{100}=0.085$$

Since the computed value is less than one, the radioactivity of the sample is within the criteria established by this guide.

From the standpoint of public health, radionuclide levels in shellfish cannot be the only source of radionuclides considered. The basic approach specified by FRC is to limit total intake of radionuclides from *all* sources so that Radiation Protection Guides are not exceeded. Under circumstances in which the concentrations in shellfish remain well below the guidance values, there is no need for public health concern from this vector. If the concentrations approach or exceed the guides, the public health significance must be evaluated in the context of radionuclide intake from all sources so that the total exposure does not exceed the Radiation Protection Guides (*15–17*). Annual averaging of the daily radioactivity intake via shellfish is appropriate.

Control of population exposure from radionuclides occurring in the environment is accomplished either by restriction of the entry of radionuclides into the environment or through measures designed to limit the radionuclide intake from various vectors by members of the population. Both situations involve the consideration of actual or potential concentrations of radioactivity in air, water and food including shellfish. Controls should be based upon an evaluation of population exposure with respect to the radiological guides.

Acknowledgement

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REFERENCES

(*1*) NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL. Disposal of low-level radioactive waste into Pacific coastal waters. Publication 985 (1962).

(*2*) NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL. Radioactive waste disposal into Atlantic and Gulf coastal waters. Publication 655 (1959).

(*3*) PRITCHARD, D. W. Environmental factors affecting the disposal of radioactive waste materials into tidal estuaries and coastal bodies of water. Hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States, Vol 2 (January–February 1959).

(*4*) ATEN, A. H. W., Jr. Permissible concentrations of radionuclides in sea water. Health Physics 6: 114–125 (1961).

(*5*) NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL. Radioactive waste disposal from nuclear-powered ships. Publication 658 (1959).

(*6*) U.S. ATOMIC ENERGY COMMISSION. Code of federal regulations, division of State and licensee relations, Title 10, Part 20. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1965).

(*7*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*8*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*9*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of Committee II on Permissible Dose for Internal Radiation. Pergamon Press, Inc., New York, N.Y. (1959).

(*10*) NATIONAL COMMITTEE ON RADIATION PROTECTION. Maximum permissible body burdens and maximum permissible concentration of radionuclides in air and water for occupational exposure, NBS Handbook 69. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (June 5, 1959).

(*11*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*12*) COWSER, K. E. and W. S. SNYDER. Safety analysis of radionuclide release to the Clinch River. ORNL 3721, Supplement 3 (1966).

(*13*) FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Organization of surveys for radionuclides in food and agriculture. Rome (1962).

(*14*) U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, INTERLABORATORY TECHNICAL ADVISORY COMMITTEE. Routine surveillance of radioactivity around nuclear facilities. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (December 1966).

(*15*) YAMAGATA, N. Evaluation of marine contamination with radioisotopes of long half-lives. Health Physics 11:1005–1008 (October 1965).

(*16*) U.S. PUBLIC HEALTH SERVICE. Radiological Health Handbook. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*17*) UNITED KINGDOM MEDICAL RESEARCH COUNCIL. Report to the Medical Research Council by its Committee on Protection Against Ionizing Radiation. British Med J 5127:967–969 (1959).

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Radioactivity in the Mexican Environment

R. M. Nulman and M. Vasquez Barete[1]

The Comisión Nacional de Energia Nuclear in Mexico operates surveillance networks monitoring radioactivity in airborne particulates, particulates in fallout and precipitation, drinking water, milk, food, and sea water. Methods of analysis and the resultant data for 1965 and 1966 are presented. This surveillance program was instituted to provide a general picture of the radioactivity levels in the Mexican environment, protection for the Mexican people from overdoses of radiation, and information for the handling of legal claims that may arise against the Nuclear Center of Mexico (now under construction).

As part of its program of radiological surveillance, the Comisión Nacional de Energia Nuclear (CNEN) in Mexico monitors the environment of the Mexican Republic with emphasis on the site of the Nuclear Center of Mexico and its surroundings. The Nuclear Center, now under construction, will contain a one megawatt Triga Mark III research reactor and a 12 MeV tandem Van de Graff accelerator. The Center will also produce radioisotopes for domestic use and exportation (*1*).

In order to provide a general picture of the radioactivity levels in the Mexican environment, protection for the Mexican people from overdoses of radiation, and information for the handling of legal claims that may arise against the Nuclear Center, the Environmental Radioactivity Section (ERS) has developed a program to routinely survey the levels of radioactivity in Mexico and monitor the levels of environmental radioactivity at the nuclear reactor site (Nuclear Center) and its surroundings.

The CNEN operates surveillance networks monitoring radioactivity in airborne particulates, particulates in fallout and precipitation, drinking water, milk, food, and sea water. Radioactive particulates in air results are published monthly in *Radiological Health Data and Reports* (*2*) and are summarized for 1965 through 1966 in table 1. In addition, gross beta radioactivity in samples of airborne particulates taken in the vicinity of the Nuclear Center are given in table 1. When the average radioactivity at any station for the month is greater than or equal to 1 pCi/m^3, an analysis is made to determine the strontium–90, cesium–137 and potassium–40 content of a monthly composite sample from that station. In 1965 a special study was conducted on the radiochemical separation techniques using samples containing less than 1 pCi/m^3 of gross beta radioactivity. Results of these radiochemical separations for 1965 through 1966 are presented in tables 2 to 4.

Rainwater is collected in a 1-gallon polyethylene bottle using a funnel with an opening of known area. Each month, or when the bottle is ¾ full, the funnel is rinsed with a known quantity of distilled water and the sample is forwarded to the ERS laboratory in Mexico, D.F., for analysis.

Analysis begins with the filtering a 1-liter aliquot of the sample through a Millipore filter. Dissolved solids are determined by evaporating the filtrate to a small volume, transferring it to a planchet, evaporating it to dryness, and counting in a beta-particle, anti-coincidence counter. Suspended solids are determined by

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[1] Mrs. Vasquez Barete is director and Mrs. Nulman is a physicist, Comisión Nacional de Energia Nuclear, México, D.F.

Table 1. Gross beta radioactivity of airborne particulates, Mexico, 1965–1966

Average gross beta radioactivity (pCi/m³)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1965												
Acapulco	0.1	0.1	0.1	0.1	NS	0.2	<0.1	<0.1	<0.1	<0.1	NS	<0.1
Chihuahua	.2	.1	.1	.2	0.3	.3	.1	<.1	<.1	.1	0.1	<.1
Ciudad Juárez	.2	.2	.2	.2	.1	.3	.1	<.1	.1	.1	.1	.1
Ensenada	.3	.1	.2	.2	.3	.2	.1	<.1	.1	.1	.1	<.1
Guadalajara	.1	.1	.1	.1	.3	<.1	<.1	<.1	<.1	<.1	<.1	.1
Guaymas	.1	NS	.1	.2	.4	.3	<.1	<.1	<.1	.1	<.1	<.1
La Paz	.3	NS	.2	.2	.2	.3	.2	<.1	<.1	.1	<.1	<.1
Matamoros	<.1	<.1	NS	.1	.3	.3	.1	<.1	NS	<.1	NS	NS
Mazatlán	NS	NS	NS	NS	NS	.2	.1	<.1	<.1	.1	<.1	<.1
Mérida	.1	.1	.1	.1	.2	.3	<.1	<.1	<.1	<.1	<.1	<.1
México, D.F.	<.1	.1	.1	.3	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Nuevo Laredo	<.1	<.1	NS	.2	NS	.3	.1	<.1	<.1	NS	<.1	<.1
San Luis Potosí	.1	.1	<.1	<.1	.3	.3	<.1	<.1	<.1	<.1	<.1	<.1
Tampico	.2	.2	.1	.2	.1	.1	<.1	<.1	<.1	<.1	<.1	<.1
Torreón	.2	.2	.2	.2	.3	.1	.1	<.1	<.1	.1	<.1	<.1
Veracruz	.1	.1	NS	NS	NS	.3	<.1	<.1	<.1	<.1	.1	<.1
1966												
Acapulco	NS	0.3	NS	0.1	NS	NS	0.1	0.1	<0.1	0.1	0.1	0.1
Chihuahua	0.7	.6	0.3	.2	1.0	3.0	.4	.1	<.1	.1	.1	.1
Ciudad Juárez	.6	.7	.3	.2	.5	.6	.3	.1	<.1	.1	.1	.1
Ensenada	.4	NS	.2	NS	.3	NS	.2	.1	<.1	.1	.1	.1
Guadalajara	NS	.3	.2	NS	.3	NS	.1	.1	<.1	.1	NS	NS
Guaymas	.4	.5	.3	NS	.3	.6	NS	.4	<.1	NS	NS	NS
La Paz	.3	.3	.3	.2	.1	.4	.2	.1	<.1	.1	.1	.1
Matamoros	.3	NS	.2	.1	NS	NS	.3	.1	<.1	.1	NS	NS
Mazatlán	.2	.3	.3	.2	NS	.9	.2	.1	<.1	.1	.1	.1
Mérida	NS	NS	.2	.2	.6	.5	.3	.1	<.1	.1	.1	.1
México, D. F.	.3	NS	.2	NS	.1	.5	.3	.2	<.1	.1	.1	.1
Nuevo Laredo	.3	NS	.2	.2	.2	.6	.3	.2	NS	.2	NS	.1
San Luis Potosí	.3	NS	.1	.2	.6	NS	.1	.1	<.1	<.1	NS	NS
Tampico	.1	NS	.1	.1	.4	.8	.1	.1	<.1	<.1	.3	NS
Torreón	.2	.3	.3	.2	.5	.7	.3	.2	<.1	.2	.1	.1
Veracruz	.3	.3	.3	.2	.5	.4	.4	.3	<.1	.1	.1	.1
Nuclear Center							.1	.1	<.1			

NS, no sample reported.

ashing the filter and counting in a low background beta-particle counter which is calibrated with a thallium–204 standard. Results for 1965 through 1966 are presented in table 5. No radiochemical separation is made unless the radioactivity is greater than 100 pCi/liter, which is one-tenth of the maximum permissible concentration of gross beta radioactivity in drinking water for the general population. When levels are high, radiochemical separations are made for strontium–90, cesium–137 and potassium–40.

Table 2. Strontium-90 particulates in air, Mexico

Station	Concentration (pCi/1,000 m³)			
	May 1965	June 1965	July 1965	June 1966
Acapulco	NS	NA	1.07 ±0.03	NS
Chihuahua	10.19 ±0.15	6.22 ±0.10	6.21 ±0.04	3.5 ±0.46
Ciudad Juárez	4.88 ±0.02	NA	3.36 ±0.06	NA
Ensenada	7.12 ±0.23	10.17 ±0.05	NA	NS
Guadalajara	11.07 ±0.15	NA	2.92 ±0.15	NS
Guaymas	3.79 ±0.2	9.22 ±1.3	0.12 ±0.02	NA
LaPaz	1.56 ±0.32	NA	4.30 ±0.04	NA
Matamoros	8.31 ±0.07	NA	NA	NS
Mazatlán	NS	12.44 ±0.11	2.37 ±0.03	1.65 ±0.03
Mérida	5.60 ±0.41	0.42 ±0.03	0.95 ±0.03	NA
México, D. F	10.38 ±0.45	7.06 ±0.21	1.55 ±0.03	NA
Nuevo Laredo	NS	3.73 ±0.04	2.06 ±0.03	NA
San Luis Potosí	1.01 ±0.03	2.82 ±0.03	2.59 ±0.02	NS
Tampico	3.43 ±0.05	6.20 ±0.05	0.13 ±0.05	NA
Torreón	4.44 ±0.08	3.35 ±0.20	6.06 ±0.11	NA
Veracruz	NS	6.13 ±0.13	3.81 ±0.07	NA

NS, no sample reported.
NA, no analysis performed.

Table 3. Cesium-137 particulates in air, Mexico

Station	Concentration (pCi/1,000 m³)				
	June 1965	July 1965	Aug 1965	Sept. 1965	June 1966
Acapulco	NA	NA	NA	NA	NS
Chihuahua	3.40 ±0.02	7.4 ±0.42	6.68 ±0.56	6.16 ±0.16	4.8 ±0.29
Cuidad Juárez	NA	NA	1.56 ±0.90	NA	NA
Ensenada	NA	NA	NA	NA	NS
Guadalajara	NA	NA	NA	NA	NS
Guaymas	NA	NA	NA	NA	NA
LaPaz	NA	NA	NA	NA	NA
Matamoros	NA	NA	NA	NS	NS
Mazatlán	NA	NA	NA	NA	6.0 ±0.30
Mérida	NA	7.10 ±0.60	NA	NA	NA
México, D. F	NA	NA	NA	NA	NA
Nuevo Laredo	NA	NA	NA	NA	NA
San Luis Potosí	NA	6.02 ±0.26	NA	NA	NS
Tampico	5.71 ±0.79	6.08 ±0.30	NA	NA	NA
Torreón	NA	NA	1.50 ±0.27	NA	NA
Veracruz	NA	NA	NA	NA	NA

NS, no sample reported:
NA, no analysis performed.

Table 4. Potassium-40 particulates in air, Mexico

Station	Concentration (pCi/1,000 m³)			
	May 1966	June 1966	July 1966	June 1966
Acapulco	NS	NA	1.40	NS
Chihuahua	1.12	0.86	1.12	1.13
Ciudad Juárez	2.16	NA	2.11	NA
[illegible]	2.23	1.40	NA	NS
Guadalajara	0.88	NA	1.72	NS
Guaymas	1.86	1.36	2.68	NA
La Paz	0.10	NA	1.65	NA
Matamoros	1.01	NA	NA	NS
[illegible]	NS	0.86	1.60	0.39
Mérida	1.34	1.09	1.18	NA
México, D. F.	2.23	1.12	3.72	NA
Nuevo Laredo	NS	2.01	2.79	NA
San Luis Potosí	1.80	1.38	1.72	NA
Tampico	1.12	1.46	1.62	NA
Torreón	1.31	1.86	1.17	NA
Veracruz	NS	0.93	1.39	NA

NS, no sample reported.
NA, no analysis performed.

Drinking water is sampled weekly in Mexico City and monthly from areas around the Nuclear Center. The monthly sample, or a monthly composite of the weekly samples, is analyzed for gross beta radioactivity on dissolved and suspended solids by the same procedure used for rainwater (4). Radiochemical analyses are made for strontium-90, cesium-137 and potassium-40 only if the gross beta radioactivity in the composite is greater than one-tenth of the maximum permissible concentration of gross beta radioactivity in drinking water for the general population. The results for 1966 are presented in table 6. Rivers and lakes in the vicinity of the Nuclear Center are sampled and analyzed by the same method used for drinking water. The results are given in table 7.

Monthly composites of liquid milk samples collected weekly from five sampling locations in Mexico and four zones around Mexico City are analyzed for strontium-90. Two monthly powdered milk samples are also analyzed. The radiochemical procedure is based on the separation of the alkaline earth metals from milk on an ion exchange column. Then the strontium is extracted using techniques of differential solubility and liquid extraction with di-2-ethylhexyl-phosphoric acid (DEHP) in toluene.

Table 5. Gross beta radioactivity in rainwater, Mexico, 1965–1966

Station	Concentrations of gross beta radioactivity	1965					1966										
		Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Acapulco:	pCi/liter SS[a]	......	......	<3	......	......	......	......	......	< 3	10.0	21.3	< 3	<3	<3	< 3	
	DS	......	......	<3	......	......	......	......	......	9.6	12.0	17.0	7.0	<3	<3	< 3	
	nCi/m³ SS	......	......	<0.1	......	......	......	......	......	< 0.1	0.4	2.8	0.1	<0.1	<0.1	0.2	
	DS	......	......	< .1	......	......	......	......	......	< .1	.5	3.3	.1	.4	<3	0.1	
Nuclear Center:	pCi/liter SS	19.5	......	......	......	......	......	......	9.0	8.0	8.0	9.1	5.7	<3	<3	< 3	
	DS	6.6	......	......	......	......	......	......	9.5	5.3	24.4	14	< 3	<3	<3	< 3	
	nCi/m³ SS	0.9	......	......	......	......	......	......	0.4	.7	.3	0.6	.5	.8	.1	.1	
	DS	.3	......	......	......	......	......	......	.4	.5	1.1	< 1	.2	.2	.1	.3	
Chihuahua:	pCi/liter SS	......	......	......	......	......	......	......	< 3	< 3	46.5	< 3	......	<3	<3		
	DS	......	......	......	......	......	......	......	9.1	< 3	30.0	3.6	......	<3	6.2		
	nCi/m³ SS	......	......	......	......	......	......	......	.1	.3	3.9	.3	......	.4	< .1		
	DS	......	......	......	......	......	......	......	.5	.2	2.7	.4	......	.8	.8		
México, D. F:	pCi/liter SS	......	......	......	......	......	......	......	3.3	< 3	5.9	< 3	< 3	<3	<3		
	DS	......	......	......	......	......	......	......	< 3	< 3	.1	19.3	< 3	<3	<3		
	nCi/m³ SS	......	......	......	......	......	......	......	.1	.1	.4	.1	.4	.2	< .1		
	DS	......	......	......	......	......	......	......	.1	.1	.5	3.1	.2	.3	< .1		
San Luis Potosí:	pCi/liter SS	......	......	......	......	......	......	......	......	28.5	8.6	......	< 3	<3	3.4		
	DS	......	......	......	......	......	......	......	......	15.4	38.4	......	< 3	<3	8.9		
	nCi/m³ SS	......	......	......	......	......	......	......	......	.6	.4	......	< .1	< .1	.2		
	DS	......	......	......	......	......	......	......	......	.3	1.7	......	< .1	< .1	.5		
Torreón:	pCi/liter SS	......	61.6	......	......	20.5	......	......	19.4	17.7	26.3	50.7	23.2	4.7	3.2	13.7	<3
	DS	......	19.4	......	......	5.9	......	......	78.3	28.0	38.3	82.9	31.2	3.1	4.1	30.5	<3
	nCi/m³ SS	......	2.7	......	......	.9	......	......	2.0	.1	1.1	1.5	.3	.4	.1	.1	<0.1
	DS	......	0.8	......	......	0.3	......	......	.8	.5	1.7	1.6	.3	.3	.2	.3	< .1
Veracruz:	pCi/liter SS	......	......	......	......	......	13.8										
	DS	......	......	......	......	......	3.8										
	nCi/m³ SS	......	......	......	......	......	.6										
	DS	......	......	......	......	......	0.2										

[a] SS, suspended solids.
DS, dissolved solids.

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Table 6. Gross beta radioactivity in drinking water, Mexico, 1966

Station	Sample fraction	Average concentrations (pCi/liter)										
		Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Colonia Ortiz Rubio	SS	...	...	<3	3.4	<3	...	<3	<3	<3		
	DS	...	...	<3	4.4	<3	...	<3	<3	<3	<3	<3
[illegible]	SS	<3	...	...	5.5	5.0	...	<3	<3	<3	...	<3
	DS	10.0	...	...	<3	<3	...	<3	5.2	<3	...	<3
Lerma de Villada	SS	...	...	...	...	...	...	<3	...	<3	<3	
	DS	...	...	...	...	...	9.3	<3	...	4.6	<3	
Salazar	SS	...	5.2	...	<3							
	DS	...	<3	...	<3							
San Miguel Ameyalco	SS	...	...	...	...	...	<3	<3	<3	<3	<3	<3
	DS	...	...	...	...	...	3.5	5.1	<3	<3	<3	<3
Cuajimalpa	SS	...	...	4.0	...	...	...	...	<3	...	<3	<3
	DS	...	...	<3	...	...	...	...	<3	...	<3	<3
Joquicingo	SS	...	<3									
	DS	...	5.3									
San Ignacio Allende	SS	...	...	<3	16.0	3.3	<3	...	<3	6.0	...	<3
	DS	...	...	<3	<3	<3	<3	...	<3	<3	...	<3
San Mateo Atarasquillo	SS	...	...	...	15.1	3.6	...	<3	<3	<3	<3	<3
	DS	...	...	...	<3	<3	...	5.2	<3	<3	<3	<3
San Pedro Atlapulco	SS	...	<3	<3	4.1	<3	...	<3	<3	<3	<3	
	DS		<3	<3	6.1	<3	...	<3	<3	<3	<3	
San Jeronimo Acazulco	SS	...	...	<3	<3	<3	<3					
	DS	...	...	<3	<3	3.7	10.2					
El Zarco	SS	...	<3	...	...	<3	71.3					
	DS	...	4.0	...	...	<3	<3					
Ocoyoacac	SS	...	2.4	<3	...	<3	<3	<3	<3	...	<3	<3
	DS	...	7.3	5.3	...	<3	<3	<3	<3	...	<3	<3
México, D.F.	SS	...	...	...	...	1.8	<3	<3	<3			
	DS	...	...	...	...	1.9	4.2	10.1	<3			
Nuclear Center	SS	3.4	<3	<3	...	...	...	<3	<3			
	DS	5.6	<3	<3	...	...	...	<3	<3			

SS, suspended solids.
DS, dissolved solids.

Table 7. Gross beta radioactivity in rivers and lakes, Mexico, 1966

Station	Sample fraction	Average concentrations (pCi/liter)										
		1966										
		Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
River water:												
Salazar	SS	...	5.2	...	...	...	6.1	...	3.0	...	...	<3
	DS	...	3.0	...	...	...	8.8	...	3.0	...	...	<3
Huixquilucan	SS	...	...	...	3.4	5.3	<3	4.6	<3	<3	...	<3
	DS	...	...	...	3.5	3.1	4.0	<3	7.9	<3	...	<3
El Zarco	SS	...	...	4.6	...	...	...	<3	<3	<3	<3	<3
	DS	...	...	<3	...	...	...	<3	<3	<3	<3	<3
Ocoyoacac	SS	...	<3	3.6	...	<3	...	...	<3			
	DS	...	<3	4.6	...	<3	...	...	<3			
San Pedro Atlapulco	SS	...	...	5.0	<3							
	DS	...	...	<3	4.5							
San Jeronimo Acazulco	SS	...	...	...	...	3	...	...	<3			
	DS	...	...	...	...	13.3	...	...	3.7			
San Miguel Ameyalco	SS	...	...	...	...	...	...	5.0				
	DS	...	...	...	...	...	...	6.8				
Cuajimalpa	SS	...	...	...	...	...	...	...	<3	...	<3	<3
	DS	...	...	...	...	...	...	...	<3	...	<3	3.0
Joquicingo	SS	...	...	...	...	<3						
	DS	...	...	...	...	<3						
Rio Lerma	SS	...	10.6	...	...	...	...	...	<3	<3	<3	
	DS	...	11.6	...	...	...	...	...	<3	<3	3.9	
Lake water:												
El Zarco	SS	4.8										
	DS	<3										
Salazar	SS	...	...	...	...	...	...	...	...	...	...	<3
	DS	...	...	...	...	...	...	...	...	...	...	<3
[illegible]	SS	...	...	7.8								
	DS	...	...	NA								

SS, suspended solids.
DS, dissolved solids.
NA, no analysis.

Table 8. Strontium-90 in Mexico milk, December 1965 and calendar year 1966

Station	Strontium-90 concentration	1965 Dec	1966 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Toluca	pCi/liter	----	----	<1	----	1.6±0.3	1.1±0.9	2.4±1.1	<1	2.1±0.7	<1	----	<1	1.1±0.5
	pCi/g Ca	----	----	<1	----	1.4± .8	<1	2.1±0.9	<1	1.8± .6	<1	----	<1	0.8± .4
Chalco	pCi/liter	----	1.2±0.6	<1	3.3±0.8	1.0± .5	8.0±2.7	<1	<1	<1	<1	----	<1	<1
	pCi/g Ca	----	0.9± .4	<1	2.5± .6	<1	6.3±2.1	<1	<1	<1	<1	----	<1	<1
Coapa	pCi/liter	----	3.1±1.1	1.0±0.9	7.5±2.4	<1	<1	<1	----	<1	----	----	<1	1.6± .1
	pCi/g Ca	----	2.3± .6	<1	6.7±2.2	<1	<1	<1	----	<1	----	----	<1	1.2± .5
Texcoco	pCi/liter	----	1.2± .4	1.0± .5	3.5±1.1	1.5± .6	2.3±1.1	<1	<1	<1	----	----	<1	1.7± .6
	pCi/g Ca	----	.9± .3	<1	2.9± .9	1.5± .5	1.4± .7	<1	<1	<1	----	----	<1	1.3± .7
Mérida	pCi/liter	<1	----	1.0± .6	5.0±1.7	----	1.0±1.0	2.3±1.2	----	----	----	<1		
	pCi/g Ca	<1	----	<1	3.8±1.3	----	<1	2.3±1.2	----	----	----	<1		
San Juan del Río	pCi/liter	----	2.6±1.1	1.9± .1	6.5±2.9	<1	3.9±1.3	1.9±1.9	----	2.8±1.3	<1	----	<1	1.0± .6
	pCi/g Ca	----	1.9± .8	1.6± .1	5.1±2.2	<1	3.2±1.1	1.5±1.3	----	2.5±1.2	<1	----	<1	1.4± .4
Veracruz	pCi/liter	1.6±0.5	1.5± .6	1.2±1.3	4.7±1.9	2.7±1.0	1.3± .5	<1	2.5±1.4	4.0±2.4	6.0±1.8	<1	4.9±1.1	<1
	pCi/g Ca	1.3± .4	1.5± .5	1.4±1.2	5.3±1.9	1.9± .8	1.3± .7	<1	3.1±1.1	3.9±1.7	4.8±1.0	<1	3.8±0.9	<1
Mexico, D.F.	pCi/liter	----	----	----	----	----	----	----	2.1±0.9	----	----	----	----	2.4± .9
	pCi/g Ca	----	----	----	----	----	----	----	2.0± .9	----	----	----	----	2.4± .4
Ensenada	pCi/liter	----	----	----	----	----	<1	----	----	4.9±1.5	----	----	<1	
	pCi/g Ca	----	----	----	----	----	<1	----	----	4.5±1.6	----	----	<1	
Huixquilucan	pCi/liter	----	----	----	----	----	----	----	----	----	----	<1	1.8± .7	2.0± .8
	pCi/g Ca	----	----	----	----	----	----	----	----	----	----	<1	1.3± .6	2.6±1.0
Chihuahua	pCi/liter	1.5±1.1	----	2.3±2.2										
	pCi/g Ca	1.1± .8	----	1.9±1.8										
San Mateo Atarasquillo	pCi/liter	----	----	----	----	----	----	----	----	----	----	----	<1	<1
	pCi/g Ca	----	----	----	----	----	----	----	----	----	----	----	<1	<1
Lagos *	pCi/liter	----	1.6± .9	----	2.9±1.1	----	1.5± .5	3.3±1.3	5.0±1.2	2.5± .7	6.7±1.0	1.6±0.2	5.3± .9	
	pCi/g Ca	----	1.3± .7	----	2.3± .9	----	1.1± .3	2.6±1.1	2.3±0.9	1.6± .5	4.3±0.7	1.1± .1	4.3± .8	
Tamuin *	pCi/liter	----	3.9± .5	----	1.2± .8	<1	----	<1	----	3.3±1.7	1.9± .6			
	pCi/g Ca	----	2.5± .3	----	1.0± .6	<1	----	<1	----	1.6±1.3	1.5± .4			

* Powdered milk sampling station.

Yttrium-90 is allowed to ingrow and is then extracted with DEHP and the organic layer is stripped with 3 *N* nitric acid. The carrier-free yttrium-90 is counted in a low-background anticoincidence counter. The chemical yield of the procedure is determined by spectrophotometric analysis of the strontium carrier remaining in the aqueous phase after extraction of the yttrium-90 for counting. The minimum detectable concentration with ±50 percent error at the 95-percent confidence level is 1 pCi/liter (*5*). The results for 1966 are given in table 8.

Fresh fruits and vegetables are purchased in season from the Mexico City area and around the Nuclear Center. The edible portions are homogenized, ashed, and counted in a low-background beta-particle counter (*6*). Results are given in table 9.

Sea water samples are taken quarterly by the Secretaria de Marina from sites 5 kilometers

Table 9. Gross beta radioactivity in foods, Mexico

Food	Sampling location	Date	Gross radioactivity (pCi/kg)
Chili	México, D.F.	8/23/66	514 (moist base)
Fish	Tamiahua	6/10/66	4,910 (moist base)
	El Sarco	12/2/64	2,300 (moist base)
		1/18/65	2,207 (moist base)
		5/6/65	3,507 (moist base)
Pulque	El Sarco	11/18/65	2,795 (moist base)
	San Ignacio Allende	8/10/66	195 (moist base)
	San Miguel Ameyalco	1/26/66	6,000 (moist base)
	Las Cruces	10/14/65	5,572 (moist base)
	San Pedro Atlapulco	8/24/66	349 (moist base)
		9/28/65	1,068 (moist base)
	San Ignacio Allende	9/14/66	815 (moist base)
	San Mateo Atarasquillo	9/3/66	1,340 (moist base)
		10/5/66	621 (moist base)
	San Jeronimo Acazulco	12/8/66	5,630 (moist base)
	Jequicingo	2/2/66	3,875 (moist base)
		4/8/66	4,414 (moist base)
Shrimp	Topolobampo	2/16/66	1,180 (moist base)
	Tamiahua	6/10/66	6,678 (moist base)
Corn	San Ignacio Allende	1/18/65	2,352 (dry base)
	San Miguel Ameyalco	3/26/65	1,501 (dry base)
Oats	Salazar	9/28/65	3,092 (dry base)
Capulin (plum):			
branches	Ocoyoacac	7/6/66	1,460 (dry base)
fruit		7/6/66	1,592 (dry base)
branches	San Mateo Atarasquillo	7/27/66	14,117 (dry base)
fruit		7/27/66	1,466 (dry base)
Onions	Ocoyoacac	8/24/66	[illegible],759 (dry base)
	San Pedro Atlapulco	12/28/66	[illegible],518 (dry base)
Milk	Huixquilucan	3/16/66	163,000 (dry base)
Horse beans	Ocoyoacac	5/20/65	482 (dry base)
		5/26/66	35,973 (dry base)
	San Ignacio Allende	7/1/65	2,201 (dry base)
		4/8/65	23,123 (dry base)
		5/6/66	195 (dry base)
	San Pedro Atlapulco	5/14/65	12,713 (dry base)
	San Miguel Ameyalco	9/29/65	53,553 (dry base)
	Mirasol	11/2/66	7,577 (dry base)

Table 10. Radiochemical analysis of sea water, Mexico

Station	Date	Beta radioactivity in insoluble sulphides (pCi/liter)	Beta radioactivity in insoluble carbonates (pCi/liter)	Beta radioactivity in soluble carbonates (pCi/liter)	Beta radioactivity in suspended solids (pCi/liter)	Gross beta radioactivity (pCi/liter)	Strontium-90 (pCi/liter)	Iodine-131 (pCi/liter)	Potassium-40 (pCi/liter)	Cesium-137 (pCi/liter)	Strontium-90 (pCi/g Ca)
Acapulco	March 1966	6.0	10.3	421.6	----------	421.6	0.6	0.4	404	0.3	2.6
	September 1966	7.5	14.0	480.4	----------	480.4	1.0	.6	457	.3	2.9
	October 1966	12.80 ±0.23	29.40 ±0.41	198.0 ±0.51	1.30	241.50					
Bahia de Todos Santos	March 1966	4.0	7.1	390.87	----------	390.87	1.5	.8	377	.4	4.9
	October 1966	5.30 ±0.30	10.34 ±0.38	243.2 ±0.43	2.23 ±0.30	260.97					
La Paz	October 1966	1.91 ±0.16	3.9 ±0.18	155.5 ±0.9							
Veracruz	September 1965	5.3	9.0	272.0	----------	272.0	.8	.6	256	.3	2.1
	September 1966	3.8	7.3	383.0	----------	383.0	.9	.7	370	.4	2.4
	October 1966	0.93 ±0.28	3.28 ±0.34	200.1 ±0.51	0.07 ±0.28	204.38					

from shore near 10 ports on the Pacific Ocean and the Gulf of Mexico. Methods of analysis are those outlined by Porter, et al. (7). Samples containing gross beta radioactivities greater than one-tenth of the maximum permissible concentration for drinking water are analyzed for strontium–90 and cesium–137. The results for 1966 are given in table 10.

REFERENCES

(1) FERNANDEZ, C. GRAEF. El programa nuclear de Mexico. (Paper presented at the International Conference on the Utilization of Research Reactors and Reactor Mathematics and Computations held at México, D.F.)

(2) COMISION NACIONAL DE ENERGIA NUCLEAR. Mexican air monitoring program, January 1967. Radiol Health Data Rep 8:296–297 (May 1967).

(3) U.S. ATOMIC ENERGY COMMISSION. Concentrations in water and air above natural background. Title 10, Code of Federal Regulations, Part 20, Standards for Protection Against Radiation 265:116e (October 11, 1961).

(4) VASQUEZ, B. M. and R. M. NULMAN. Estudios sobre la radiactivated ambiental en la Republica Mexicana, 1963–1965. Comisión Nacional de Energia Nuclear, Dirección General de Seguridad Radiologica (1966) in press.

(5) NULMAN, R. M. and A. P. BAEZ. Strontium–90 content of milk in Mexico. Revista Mexicana de Fisica 15:177–199 (1966).

(6) COULON, R., L. JEANMAIRE, and G. MICHON. Methodes d'etude de la contamination radioactive des vegetaux. Rapport C.E.A. No. 2339 (1963).

(7) PORTER, C. R., R. J. AUGUSTINE, J. J. MATUSEK, Sr., and M. W. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples, PHS Publication No. 999–RH–10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Both Federal and State agencies are involved in efforts to continuously monitor the intake of radionuclides from the diet. The most direct measure of radionuclide intake would be through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternative method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, milk is the single food item most often used in estimating the intake of selected radionuclides by the general and/or population groups. In the absence of specific dietary information, one may assume the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission of Radiological Protection (*5, 6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S Government Printing Office, Washington, D.C. 20402 (May 1965).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1965).

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National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, recent *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–June 1966	March 1967

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1. Pasteurized Milk Network
May 1967

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The Public Health Service's Pasteurized Milk Network (PMN) was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 68 stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent descrip-

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	<100	10	100 or greater	10
Barium-140	<100	10	100 or greater	10
Cesium-137	<100	10	100 or greater	10
Strontium-89	< 50	5	50 or greater	10
Strontium-90	< 20	2	20 or greater	10

[a] Two standard deviations.

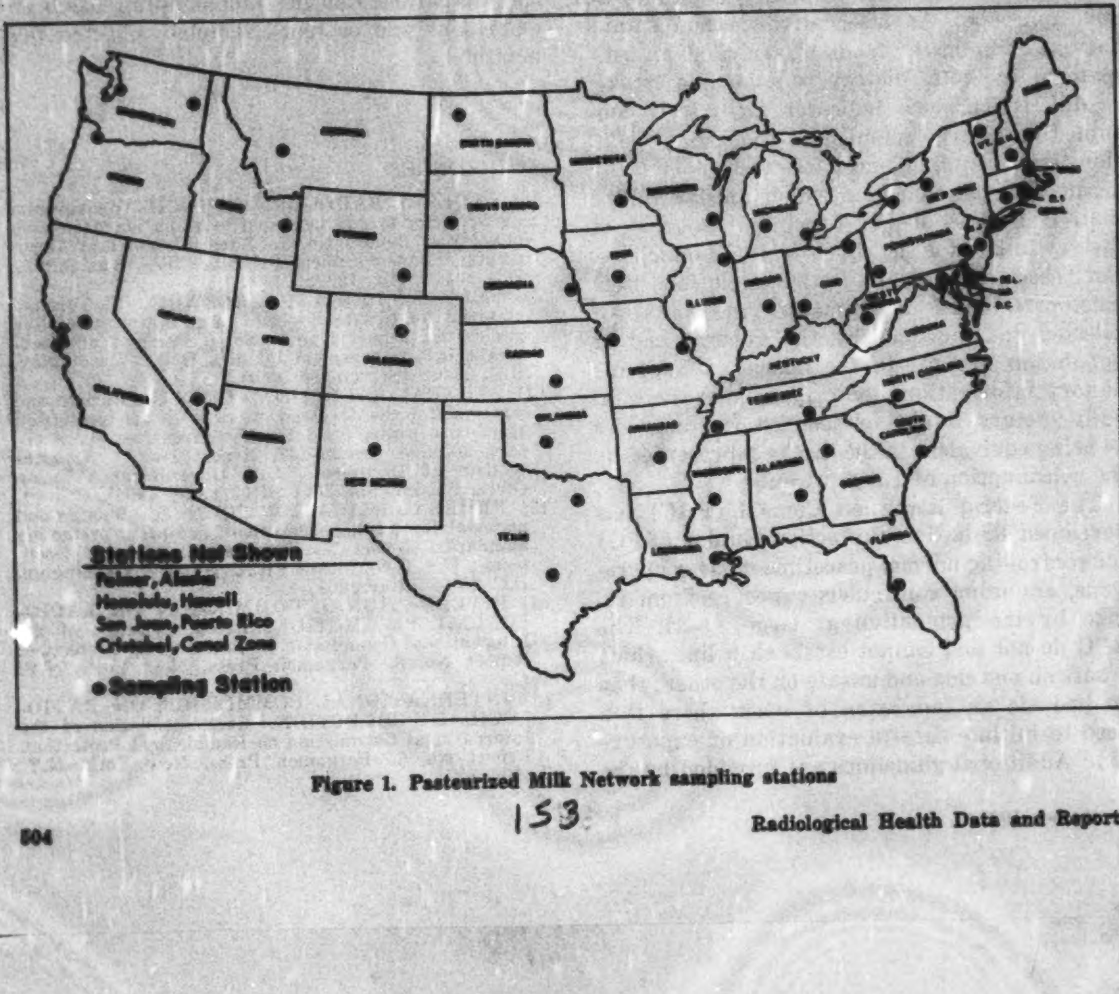

Figure 1. Pasteurized Milk Network sampling stations

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Table 2. Average concentration of radionuclides in pasteurized milk for the first quarter 1967 and May 1967

Sampling location		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Iodine-131 (pCi/liter)		Cesium-137 (pCi/liter)	
		First quarter 1967	May 1967 a	First quarter 1967	May 1967	First quarter 1967	May 1967	First quarter 1967	May 1967
Ala:	Montgomery	<5	<5	12	10	10	0	15	25
Alaska:	Palmer	<5	<5	9	7	0	0	25	25
Ariz:	Phoenix	<5	<5	2	1	0	0	<5	<5
Ark:	Little Rock	<5	<5	21	20	0	0	20	20
Calif:	Sacramento	<5	10	3	4	0	0	<5	15
	San Francisco	<5	5	4	6	0	0	<5	5
C. Z:	Cristobal	<5	<5	8	5	0	0	25	25
Colo:	Denver	<5	<5	8	5	0	0	<5	10
Conn:	Hartford			12	9	0	0	25	25
Del:	Wilmington			11	13	0	0	20	20
D. C:	Washington	<5	<5	10	10	0	0	15	15
Fla:	Tampa	<5	<5	9	9	0	0	70	30
Ga:	Atlanta	<5	<5	17	17	10	0	25	25
Hawaii:	Honolulu	<5	<5	8	4	0	0	15	10
Idaho:	Idaho Falls	<5	<5	7	7	0	0	10	15
Ill:	Chicago	<5	<5	8	10	0	0	20	15
Ind:	Indianapolis	<5		10	10	0	0	20	10
Iowa:	Des Moines	<5	5	9	10	0	0	10	15
Kans:	Wichita	<5	10	9	8	0	0	5	10
Ky:	Louisville	<5	<5	14	14	0	0	15	15
La:	New Orleans	<5	<5	27	27	0	0	25	30
Maine:	Portland	<5		13	12	0	0	45	40
Md:	Baltimore	<5	<5	11	13	0	0	20	15
Mass:	Boston	<5	<5	13	13	0	0	25	25
Mich:	Detroit			10	9	0	0	20	20
	Grand Rapids	<5		11	11	0	0	25	25
Minn:	Minneapolis	<5	5	14	12	0	0	15	20
Miss:	Jackson	<5	<5	21	21	10	0	20	20
Mo:	Kansas	<5	10	10	9	0	0	5	10
	St. Louis	<5	10	11	10	0	0	10	10
Mont:	Helena	<5	<5	7	6	0	0	10	15
Nebr:	Omaha	<5	<5	10	6	0	0	10	10
Nev:	Las Vegas	<5	<5	3	1	0	0	<5	5
N. H:	Manchester	<5		16	15	0	0	45	30
N. J:	Trenton	<5		10	10	0	0	25	20
N. Mex:	Albuquerque	<5	<5	5	3	0	0	<5	10
N. Y:	Buffalo	<5		9	9	0	0	20	20
	New York City	<5		11	13	0	0	20	25
	Syracuse	<5		9	10	0	0	20	20
N. C:	Charlotte	<5	<5	18	19	0	0	20	15
N. Dak:	Minot	<5	10	17	19	0	0	15	20
Ohio:	Cincinnati	<5		11	12	0	0	20	15
	Cleveland	<5		12	11	0	0	20	25
Okla:	Oklahoma City	<5	<5	10	12	0	0	10	15
Ore:	Portland	5	<5	8	9	0	0	10	15
Pa:	Philadelphia	<5		11	9	0	0	20	20
	Pittsburgh			13	15	0	0	25	30
P. R:	San Juan	<5	<5	5	4	0	0	15	15
R. I:	Providence	<5		11	11	0	0	30	30
S. C:	Charleston	<5	<5	18	15	20	0	30	40
S. Dak:	Rapid City	<5	10	11	13	0	0	15	15
Tenn:	Chattanooga	<5	<5	16	17	0	0	20	15
	Memphis	<5	<5	13	16	0	0	10	10
Tex:	Austin	<5	<5	4	4	20	0	10	10
	Dallas	<5	<5	9	11	10	0	10	10
Utah:	Salt Lake City	<5	<5	7	6	0	0	10	15
Vt:	Burlington	<5		11	11	0	0	35	25
Va:	Norfolk	<5	<5	12	14	0	0	15	15
Wash:	Seattle	<5	5	11	14	0	0	25	40
	Spokane	<5	<5	11	13	0	0	20	20
W. Va:	Charleston	<5	<5	12	17	0	0	15	15
Wisc:	Milwaukee			8	7	0	0	20	20
Wyo:	Laramie	<5	<5	7	4	0	0	10	10
Network average		<5	<5	10.7	10.8	0	0	20	20

a Blank indicates no strontium-89 determinations were made on samples from station during month.

tion of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. The results for May 1967 and first quarter of 1967 are presented in table 2. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable values; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 3 and 4 for May 1966 and December 1966 through May 1967. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 3. Frequency distribution, strontium–90 concentrations in milk at PMN stations, May 1966, December 1966–May 1967

Strontium–90 (pCi/liter)	Number of stations						
	1966		1967				
	May	Dec	Jan	Feb	Mar	Apr	May
Under 10	19	26	24	21	22	25	22
10–19	28	33	36	35	35	34	33
20–29	12	5	3	4	3	4	3
30–39	3	0	0	0	1	0	0

Table 4. Frequency distribution, cesium–137 concentrations in milk at PMN stations, May 1966, December 1966–May 1967

Cesium–137 (pCi/liter)	Number of stations						
	1966		1967				
	May	Dec	Jan	Feb	Mar	Apr	May
Under 80	51	62	62	62	62	62	61
80–99	11	1	1	1	1	1	2
100–140	1	0	0	0	0	0	0

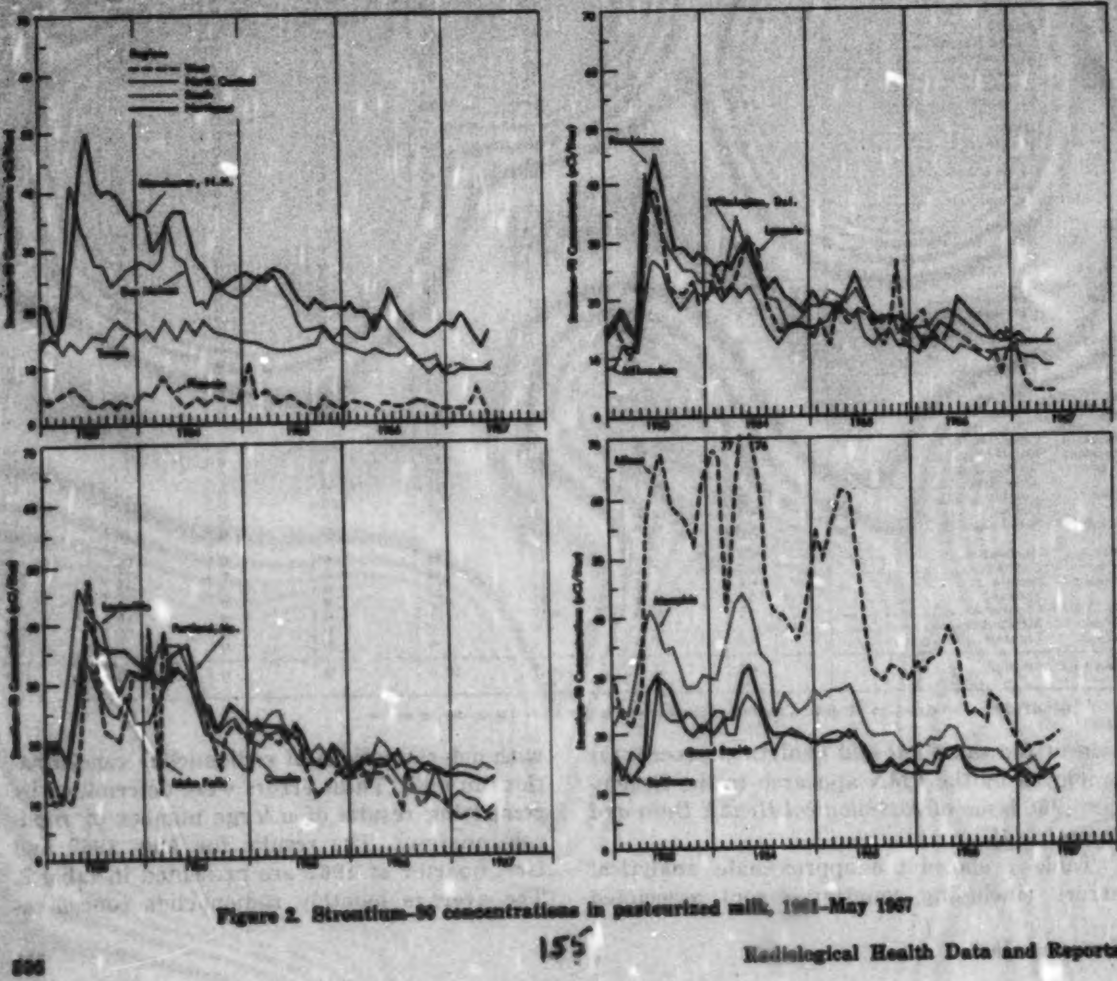

Figure 2. Strontium–90 concentrations in pasteurized milk, 1963–May 1967

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2. Canadian Milk Network May 1967[1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December 1966 issue of *Radiological Health Data and Reports* (2).

The May 1967 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

Table 5. Stable element and radionuclides in Canadian whole milk, May 1967

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.08	NS	12	NS
Edmonton	1.10	1.4	13	39
Ft. William	1.10	1.5	15	44
Fredericton	1.11	1.5	21	53
Halifax	1.11	1.5	15	42
Montreal	1.08	1.4	13	29
Ottawa	1.13	1.4	12	30
Quebec	1.07	1.4	16	57
Regina	1.07	1.4	14	37
St. John's. Nfld	1.10	1.4	20	61
Saskatoon	1.09	1.5	13	29
Sault Ste. Marie	1.11	1.4	21	51
Toronto	1.14	1.5	7	26
Vancouver	1.16	1.5	22	73
Windsor	1.13	1.6	7	22
Winnipeg	1.18	1.7	14	48
Average	1.11	1.5	15	42

NS, no sample collected.

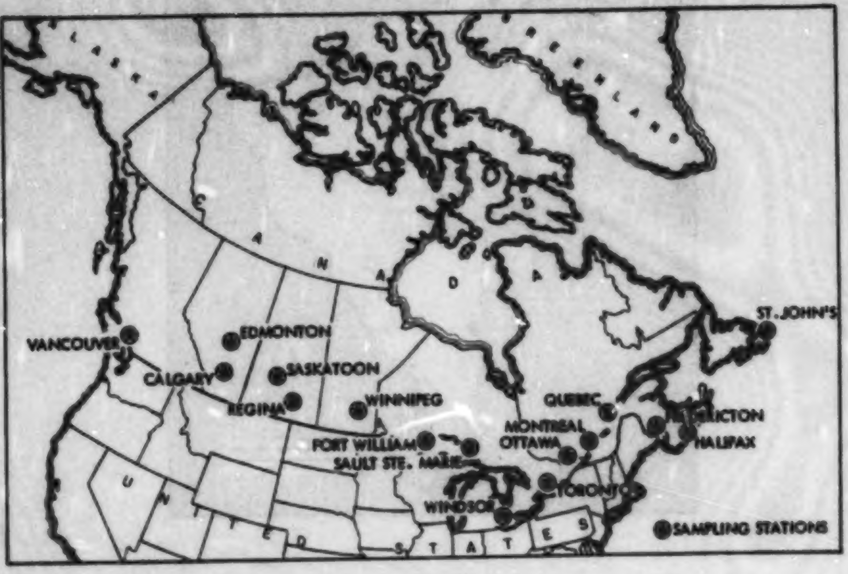

Figure 3. Canadian milk sampling stations

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[1] Prepared from June 1967 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

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3. Pan American Milk Sampling Program May 1967

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 6 presents stable potassium, strontium–90, and cesium–137 monthly average concentrations for May 1967.

Table 6. Stable element and radionuclide concentration in PAHO milk, May 1967 [a]

Sampling stations	Number of samples	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Chile:				
Santiago	1	1.66	2	15
Colombia:				
Bogota	1	1.47	3	10
Ecuador:				
Guayaquil	1	1.60	<1	<5
Jamaica:				
Kingston	NS			
Mandeville	1	1.42	8	80
Montego Bay	NS			
Venezuela:				
Caracas	NS			
Canal Zone:				
Cristobal [b]	4	----------	5	35
Puerto Rico:				
San Juan [b]	4	----------	4	15

[a] Iodine-131 and barium-140 determinations were less than 10 pCi/liter for all samples. Strontium-89 was less than 5 pCi/liter for all samples.

[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone and San Juan, Puerto Rico, from the Pasteurized Milk Network, are presented.

NS, no sample collected.

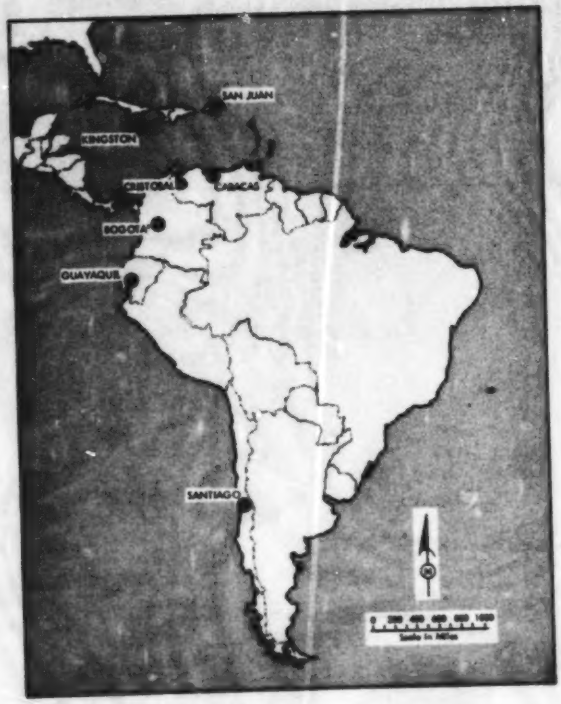

Figure 4. Pan American Milk Sampling Program locations

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4. Radiostrontium in milk July–December 1966[2]

Health and Safety Laboratory
U.S. Atomic Energy Commission

In 1954, the Health and Safety Laboratory began monitoring strontium-90 in liquid whole milk in New York to estimate the dietary contribution from ingestion of radiostrontium in milk. Subsequently, powdered milk monitoring was initiated at Perry, N.Y. (1954), and at Mandan, N. Dak. (1955). Liquid whole milk monitoring was started in Honolulu, Hawaii, in August 1959. Sampling was terminated at Mandan, N. Dak., and Honolulu, Hawaii at the end of June 1965.

The New York City sample is a monthly composite of pasteurized milk purchased daily in quart containers at retail stores. Five large dairies are represented in the sample. The Perry samples are monthly composites of powdered whole milk for human consumption collected weekly in 5-pound lots from plants in the city. The strontium-90 to calcium ratios in whole milk are presented in table 7.

Table 7. Strontium-90/calcium ratios in milk July–December 1966

Sampling location	Strontium-90/calcium ratio (pCi ^{90}Sr/g Ca)					
	July	Aug	Sept	Oct	Nov	Dec
New York, N.Y. (liquid whole milk)	12.4	13.0	13.2	7.4	9.0	7.2
Perry, N.Y. (powdered whole milk)	13.4	13.6	12.2			

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	June 1966
January–June 1966	March 1967

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7: 698–701 (December 1966).

(*2*) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704–705 (December 1966).

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[2] Data summarized from "Fallout Program Quarterly Report," HASL-182, available from Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Va. 22151.

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows those States which report milk surveillance activities in *Radiological Health Data and Reports*. States having programs appearing in the current issue are highlighted in the figure. A summary of State programs previously covered, the reporting period, and issue of appearance are as follows:

State milk network	Period covered	Last presented
Colorado	January–March 1967	July 1967
Connecticut	January–March 1967	August 1967
Florida	April–June 1966	October 1966
Indiana	January-March 1967	August 1967
Iowa	January–March 1967	August 1967
Michigan	January–March 1967	August 1967
Minnesota	January–March 1967	August 1967
New York	January–March 1967	August 1967
Oklahoma	January–March 1967	July 1967
Pennsylvania	January–March 1967	August 1967
Tennessee	January–March 1967	July 1967
Texas	January–March 1967	July 1967

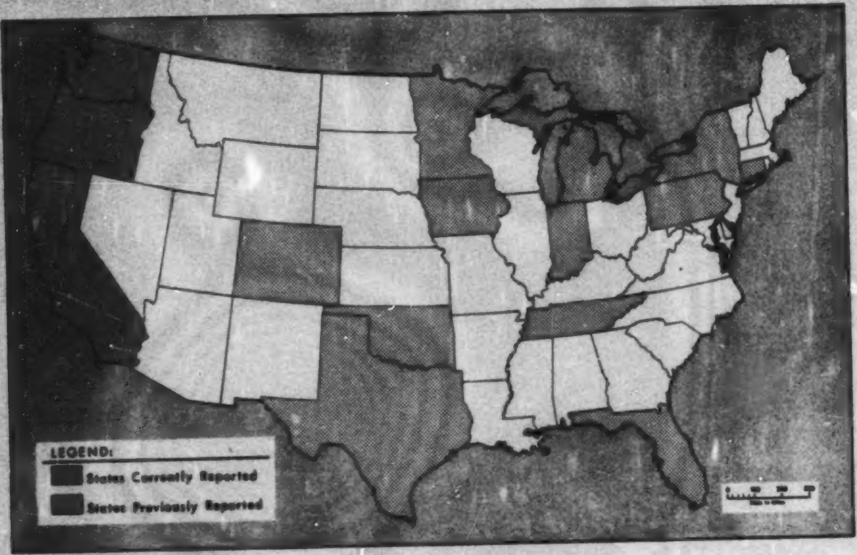

Figure 1. State milk programs reported

1. California Milk Network January–March 1967

Division of Environmental Sanitation State of California, Department of Public Health

Surveillance of specific radionuclides in milk is one phase of the California Department of Public Health program on radiation control. This milk monitoring function is conducted by the Department's Bureau of Radiological Health at 10 major milksheds (figure 2).

In January 1960, the eight original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. The Del Norte and Mendocino milksheds were added to the program in March 1962 and since that time, weekly, biweekly or monthly sampling of pasteurized milk has been conducted in 10 milkshed areas of the State. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine–131, cesium–137, and barium–140 in whole fluid milk are determined by gamma-scintillation spectrometry. A detailed description of the analytical procedures was presented in an earlier report (*2*).

The monthly calcium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period of January to March 1967.

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 3.

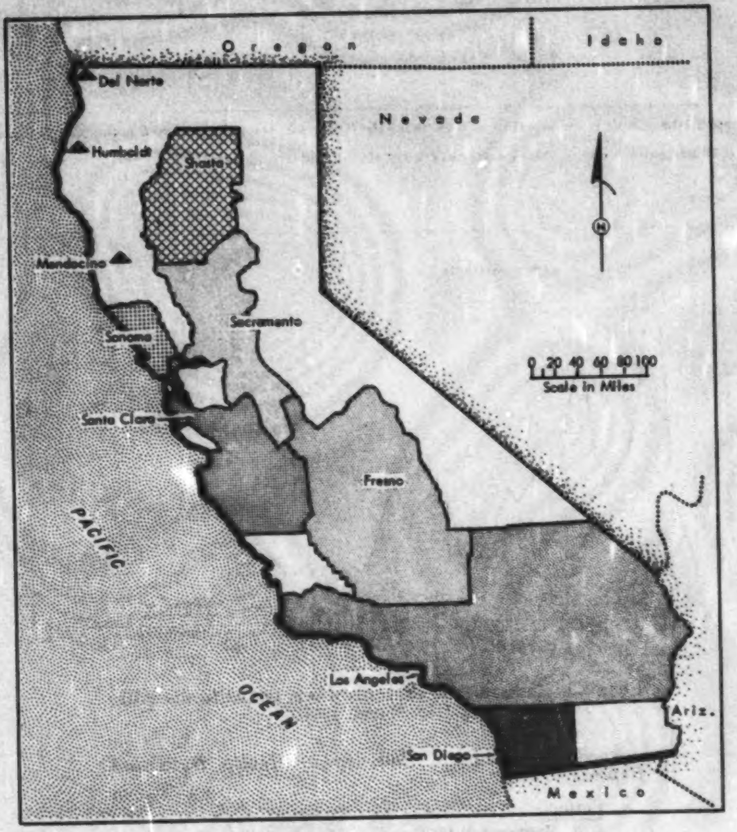
Oregon
Idaho
Nevada
Del Norte
Humboldt
Shasta
Mendocino
Sonoma
Sacramento
Santa Clara
Fresno
N
0 20 40 60 80 100
Scale in Miles
PACIFIC
OCEAN
Los Angeles
San Diego
Ariz.
Mexico

Figure 2. California milksheds

Table 1. Stable element and radionuclides in California milk, January–March 1967

Sampling location	Del Norte	Fresno	Humboldt	Los Angeles	Mendocino	Sacramento	San Diego	Santa Clara	Shasta	Sonoma	Average[b]
Calcium (g/liter)											
January	1.29	1.27	1.21	1.14	1.10	1.24	1.13	1.17	1.18	1.17	1.20
February	NS	1.22	1.21	1.12	1.20	1.21	1.18	1.13	1.19	1.20	1.18
March	1.30	1.33	1.24	1.13	1.10	1.20	1.14	1.12	1.18	1.16	1.19
Potassium-40 (pCi/liter)											
January	1,080	1,205	1,130	1,215	1,250	1,260	1,225	1,180	1,170	1,260	1,208
February	NS	1,210	1,185	1,230	1,280	1,160	1,260	1,205	1,175	1,290	1,222
March	1,060	1,090	1,135	1,250	1,160	1,185	1,265	1,280	1,115	1,155	1,168
Strontium-89 (pCi/liter)											
January	22	ND	12	ND	1	[a]1	[a]1	[a]1	[a]1	ND	6
February	NS	ND	3	ND	ND	ND	ND	ND	ND	[a]2	3
March	37	ND	8	ND	8	[a]1	ND	[a]2	[a]2	4	7
Strontium-90 (pCi/liter)											
January	21	4	7	2	3	3	1	2	5	4	5
February	NS	4	6	3	3	4	2	2	4	4	4
March	14	7	6	2	7	3	2	4	3	4	5
Iodine-131 (pCi/liter)											
January	[a]20	[a]5	20	4	[a]4	17	[a]8	[a]12	10	[a]9	12
February	NS	[a]6	12	14	[a]5	12	5	[a]9	[a]7	[a]7	9
March	40	13	16	11	9	13	[a]3	[a]8	[a]7	10	13
Cesium-137 (pCi/liter)											
January	72	24	59	7	[a]8	[a]17	[a]9	[a]18	[a]14	[a]12	24
February	NS	[a]5	ND	[a]3	ND	ND	[a]3	[a]2	[a]6	ND	4
March	ND	ND	ND	ND	[a]5	ND	ND	[a]3	ND	ND	4
Barium-140 (pCi/liter)											
January	43	[a]1	33	[a]15	[a]11	[a]24	12	[a]12	32	[a]18	20
February	NS	[a]10	[a]5	13	[a]13	20	[a]9	[a]12	[a]55	[a]6	16
March	25	30	20	[a]16	[a]10	[a]6	[a]4	[a]8	19	ND	15

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant.

[b] Estimate of average if 10 percent or more of values averaged are not statistically significant.

NS, no sample collected

ND, non-detectable.

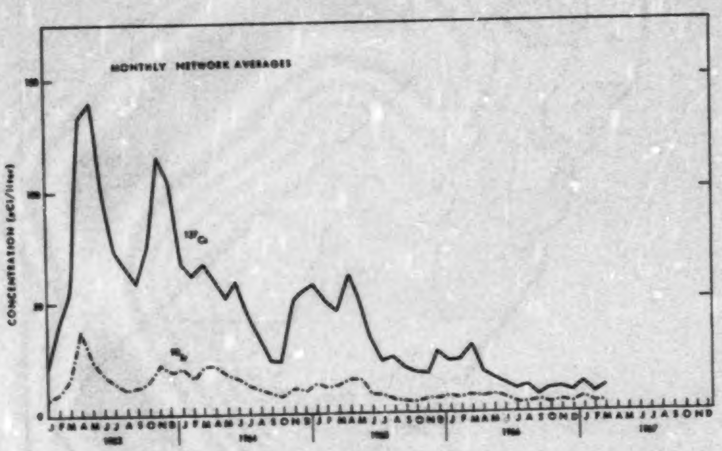

Figure 3. Radionuclide concentrations in California milk, 1963–March 1967

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	March 1967
October–December 1966	June 1967

2. Oregon Milk Network January–March 1967

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine milk samples are collected at seven major production areas (figure 4), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture except in the Portland area where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or where cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

Strontium–90 concentrations are determined using a trichloracetic-acid analytical procedure (*3*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-scintillation spectrometry (*4*).

Table 2. Radionuclide concentrations in Oregon pasteurized milk, January–March 1967

Location	Sampling frequency [a]	Radionuclide concentration (pCi/liter)					
		Strontium–90			Cesium–137		
		January	February	March	January	February	March
Baker	M	8	NA	7	<15	<15	<15
Coos Bay	M	15	NA	14	41	16	50
Eugene	M	12	NA	12	65	22	31
Medford	M	6	NA	8	30	19	20
Portland composite	W	15	NA	10	22	21	15
Portland local	W	17	NA	16	23	23	27
Redmond	M	7	NA	5	18	30	32
Tillamook	M	16	NA	22	37	35	18
Average	--	12	......	12	33	24	27

[a] M, sampled monthly.
W, sampled weekly.
NA, no analysis.

Table 2 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from January through March 1967. These data are presented graphically in figure 5. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter except for nine samples which were collected in January following the December 27, 1966, Chinese nuclear test (table 3). The Redmond sample, obtained on January 3, 1967, contained

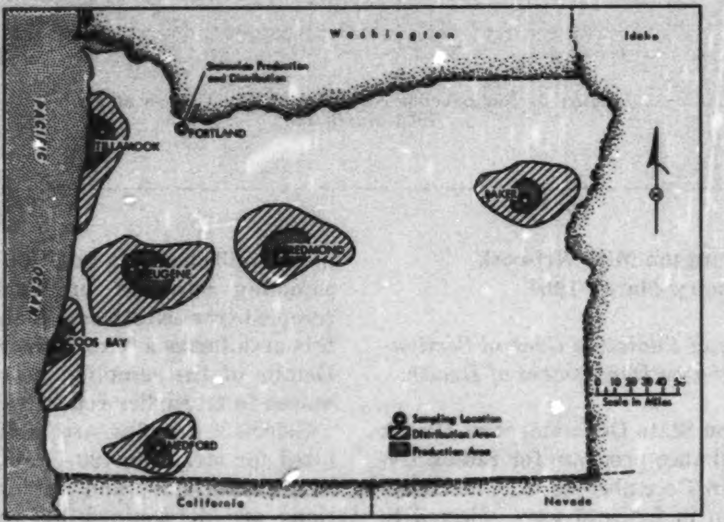
Washington
Idaho
Statewide Production and Distribution
PORTLAND
TILLAMOOK
PACIFIC OCEAN
BAKER
REDMOND
EUGENE
COOS BAY
MEDFORD
0 10 20 30 40 50
Scale in Miles
Sampling Location
Distribution Area
Production Area
California
Nevada

Figure 4. Oregon milk production and distribution areas

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115 pCi/liter of iodine-131, the Portland composite sample which was collected on January 6 had 70 pCi/liter of iodine-131 and the Brookings sample, obtained on January 24, contained 25 pCi/liter of barium-140.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1966	March 1967
October–December 1966	June 1967

Table 3. Concentrations of iodine-131 and barium-140 in Oregon milk samples, January 1967

Location	Collection date (January 1967)	Iodine-131 (pCi/liter)	Barium-140 (pCi/liter)
Portland composite	6	70	<15
Tillamook	9	40	<15
Coos Bay	3	35	<15
	10	24	<15
Eugene	3	30	20
Redmond	3	115	15
	6	20	<15
Baker	8	20	<15
Brookings	24	< 15	25

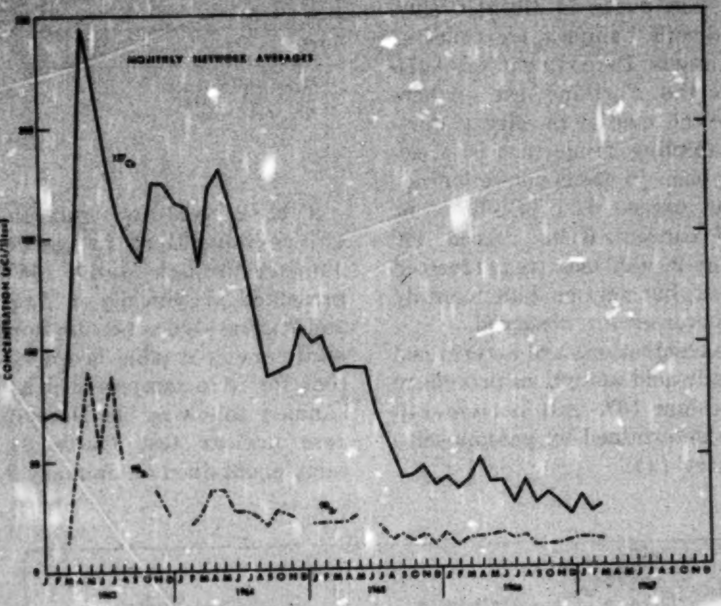

Figure 5. Radionuclide concentrations in Oregon milk, 1963–March 1967

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3. Washington Milk Network January–March 1967

Air Sanitation and Radiation Control Section
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 6 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint), as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented in an earlier report (*5*).

Selected samples are radiochemically analyzed for strontium-90. Potassium-40, iodine-131, cesium-137, and barium-140 concentrations are determined by gamma-scintillation spectrometry. Details of the analytical procedures were presented earlier (*5*).

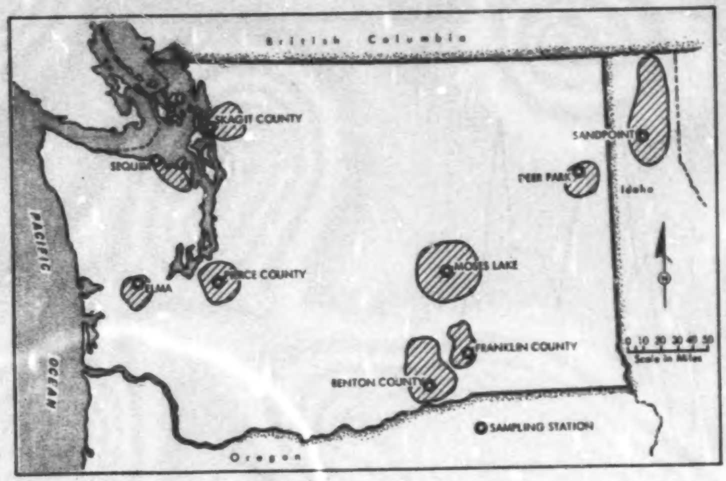

Figure 6. Washington milksheds and sampling locations

Table 4 presents monthly radionuclide concentrations in Washington raw milk for January through March 1967. Seven samples collected between January 3 and 10 showed iodine-131 levels ranging between 11 and 19 pCi/liter as a result of the December 27, 1966, Chinese nuclear detonation. Samples collected during the previous and subsequent months contained less than 10 pCi/liter of iodine-131. Barium-140 results remained below 15 pCi/liter for all samples collected during this period. Monthly average strontium-90 and cesium-137 concentrations are presented graphically in figure 7 to display general trends.

During this reporting period, four samples were collected (three from Benton County and one from Franklin County) and analyzed for zinc-65. In all four cases, zinc-65 levels were less than 25 pCi/liter. Milk samples produced in areas using Columbia River water for irrigation have periodically been found to contain this radionuclide.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July-September 1966	March 1967
October-December 1966	June 1967

REFERENCES

(1) HESLEP, J. M. and A. C. CORNISH. California milk network and milkshed comparisons, April-June 1963. Radiol Health Data 4:596-599 (December 1963).

(2) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH. California milk network, 1960-June 1962. Radiol Health Data 4:90-92 (February 1963).

Table 4. Radionuclide concentrations in Washington raw milk, January-March 1967

Sampling location	Radionuclide concentration (pCi/liter)								
	Potassium-40			Strontium-90			Cesium-137		
	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
Benton County	[a] 1,180	NS	1,180	5	NS	5	[a] 16	NS	<15
Deer Park	[a] 1,200	1,220	1,140	8	9	8	[a] 32	18	29
Elma	[a] 1,200	1,210	1,270	7	7	5	[a] 25	28	<15
Franklin County	NS	1,270	NS	NS	3	NS	NS	<15	NS
Moses Lake	[a] 1,230	1,170	1,220	[a] 6	5	5	[a] 16	<15	<15
Pierce County	[a] 1,200	1,310	1,280	7	8	10	[a] 24	25	33
Sandpoint, Idaho	[a] 1,210	1,190	1,140	23	23	25	[a] 49	41	48
Sequim	[a] 1,170	1,200	1,140	[a] 8	4	9	[a] 23	24	30
Skagit County	[a] 1,210	1,150	1,190	13	10	11	[a] 25	21	23
Average	1,200	1,215	1,195	10	9	10	26	22	24

[a] Represents an average of two or more samples collected at these sampling locations during the month.
NS, no sample collected.

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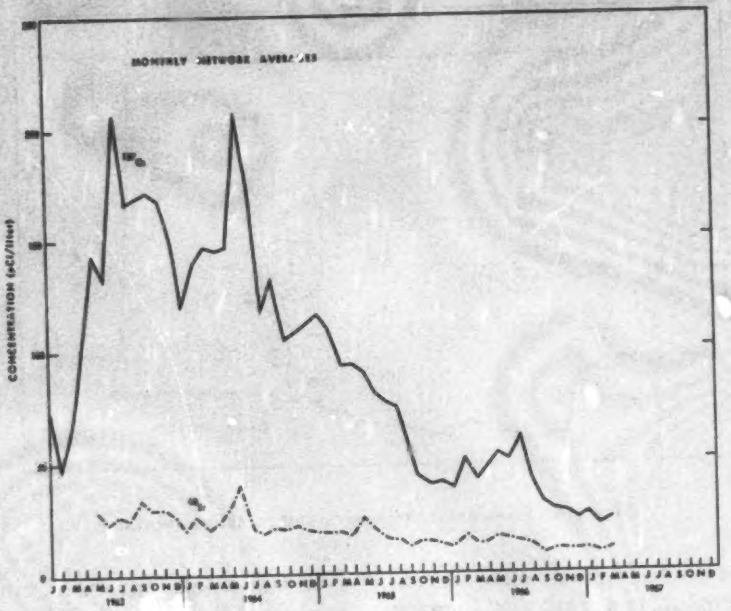

Figure 7. Radionuclide concentrations in Washington milk, 1963–March 1967

(3) MURTHY, G. K., J. E. COAKLEY, and J. E. CAMPBELL. A method for the elimination of ashing in strontium-90 determinations in milk. J Dairy Sci 43:151–154 (1960).

(4) OREGON STATE BOARD OF HEALTH, DIVISION OF SANITATION AND ENGINEERING. Oregon milk network, April–June 1965. Radiol Health Data 6:683–684 (December 1965).

(5) STATE OF WASHINGTON DEPARTMENT OF HEALTH, AIR SANITATION AND RADIATION CONTROL SECTION. Washington milk network, January–June 1965. Radiol Health Data 6:619–621 (November 1965).

Food and Diet Surveillance Activities

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intake of radionuclides. Periodically, results from the United Kingdom Diet Survey, conducted by the United Kingdom Agricultural Research Council Radiobiological Laboratory, are presented for comparison with data observed in the United States. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet Study	May–August 1966	May 1967
Connecticut Standard Diet	July–December 1966	May 1967
Institutional Diet, PHS	October–December 1966	July 1967
Teenage Diet, FDA	February–November 1965	August 1966
United Kingdom Diet	Annual summary 1965	December 1966

1. Strontium-90 in Tri-City Diets August–December 1966[1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Since March 1960, the Health and Safety Laboratory, through its quarterly diet study, has made estimates of the strontium-90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these 3 cities every 3 months on a staggered basis (*i.e.*, New York City, August 1966; San Francisco, September 1966; and Chicago, October 1966) and are analyzed for strontium-90. Fourteen of the diet categories are analyzed on a quarterly basis. Eggs, poultry, fresh fish, shellfish, and meat are purchased quarterly, but analyzed annually. This policy was initiated in 1965 due to the lower concentrations of strontium-90 in these food categories. The contribution of these five diet categories to the total annual intake of strontium-90 over the last 4 years has been approximately 5 percent. Therefore, this figure is used to calculate their contribution to the total strontium-90 dietary intake. These values are added to contributions of the other 14 food categories to obtain quarterly estimates of annual strontium-90 intake at the 3 cities. Consumption figures used are based upon data from the Department of Agriculture (*1*).

Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radioactivity in foods as reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city, it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*2*). Calcium analyses were therefore discontinued and the average calcium content of foods was computed and used to estimate the

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[1] Data from Fallout Program Quarterly Summary Report, HASL 182. Available from the Clearinghouse for Federal Scientific & Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Va. 22151.

Table 1. Average dietary consumption and strontium-90 intake in Tri-City diet, August–December 1966

Food category	Diet (kg/yr)	Calcium (g/yr)	New York City August 1966		Chicago[b] October 1966		San Francisco September 1966		New York City[b] November 1966		San Francisco[b] December 1966	
			(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)
Bakery products	37	37.0	14.6	540	6.8	252	6.5	241	6.6	244	3.9	144
Whole grain products	11	10.0	40.3	443	33.5	369	14.0	155	16.1	177	10.6	117
Fresh vegetables	43	15.0	17.6	757	8.1	348	2.0	86	9.9	426	6.4	275
Root vegetables	17	6.1	10.2	173	6.5	111	6.9	117	10.4	177	6.0	102
Milk	221	234.4	14.7	3,249	6.2	1,370	3.0	663	10.6	2,343	1.8	398
Flour	43	8.6	14.3	615	4.7	202	5.1	219	9.3	400	4.2	181
Macaroni	3	0.7	12.0	36	5.0	15	6.6	20	6.0	18	2.3	7
Rice	3	1.1	3.3	10	1.7	5	1.7	5	2.3	7	2.0	6
Dried beans	3	2.9	5.0	15	24.4	74	21.4	65	7.0	21	13.5	41
Fresh fruit	68	12.6	3.0	204	3.8	261	2.7	184	3.2	218	1.5	102
Potatoes	45	5.8	9.1	410	4.3	194	1.0	45	3.9	176	1.5	68
Canned fruit	28	1.3	1.8	47	1.2	31	1.4	36	2.9	75	1.2	31
Fruit juices	19	1.7	8.3	158	1.6	30	2.3	44	4.1	78	1.7	32
Canned vegetables	20	4.2	11.4	228	5.8	116	2.9	58	8.9	178	3.9	78
Meat, fish, poultry, shellfish, and eggs	90	42.0	--------	[a] 362	--------	[a] 178	--------	[a] 102	--------	[a] 239	--------	[a] 183
Annual intake	--------	383	--------	7,347	--------	3,556	--------	2,040	--------	4,777	--------	1,665
Daily intake	--------	1.05	--------	19.9	--------	9.7	--------	5.6	--------	13.1	--------	4.6
pCi strontium-90/g Ca	--------	--------	--------	19	--------	9	--------	5	--------	13	--------	4

[a] Estimated as 5 percent of total intake.
[b] Data based on analyses performed for HASL by a contractor laboratory and subject to revision.

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average annual intake of this material. Details of the sampling system and a discussion of the results obtained have been summarized (2).

Results of the August to December 1966 samples are presented in table 1. The variation with time of the daily intake of strontium-90 in the three cities is plotted in figure 1. A discussion of cesium-137 intakes as reflected in the Tri-City Diet Study has been presented previously (4).

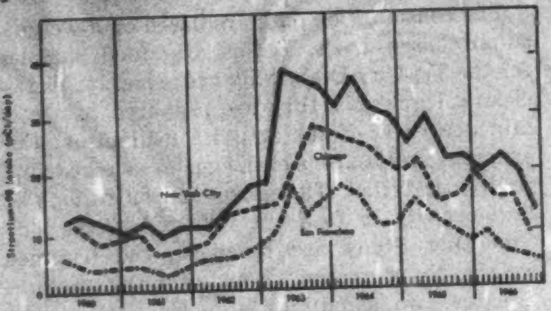

Figure 1. Daily intake of strontium-90 in Tri-City diet, March 1960–December 1966

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
November 1965–January 1966	September 1966
February–April 1966	December 1966
May–July 1966	June 1967

REFERENCES

(*1*) U.S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, household food consumption survey, Report No. 1, 1955. Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (December 1956).

(*2*) U.S. ATOMIC ENERGY COMMISSION. Fallout program quarterly summary report, HASL–144:281–287. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (April 1, 1964). Summarized in Radiol Health Data 5:285–288 (June 1964).

(*3*) RIVERA, J., and J. H. HARLEY. HASL contributions to the study of fallout in food chains, HASL–147. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (July 1, 1964).

(*4*) U.S. ATOMIC ENERGY COMMISSION, HEALTH AND SAFETY LABORATORY. Cesium-137 in Tri-City diets, 1966. Radiol Health Data Rep 8:154–157 (March 1967).

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SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when more complete analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the safe limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below:

Activity	Period reported	Last presented
California Water Sampling Program	January–June 1966	June 1967
Coast Guard Water Sampling Program	1965	November 1966
Minnesota Surface Water Sampling Program	January–June 1966	January 1967
New York Surface Water Sampling Program	June–December 1965	June 1966
Radiostrontium in Tap Water, HASL	March–November 1966	June 1967
Washington Surface Water Sampling Program	July 1965–June 1966	August 1967

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[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha emitters and strontium–90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, March 1967

Division of Pollution Surveillance
Federal Water Pollution Control Adminstration
Department of Interior

The monitoring levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha- and beta-particle analysis. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the August 1967 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly

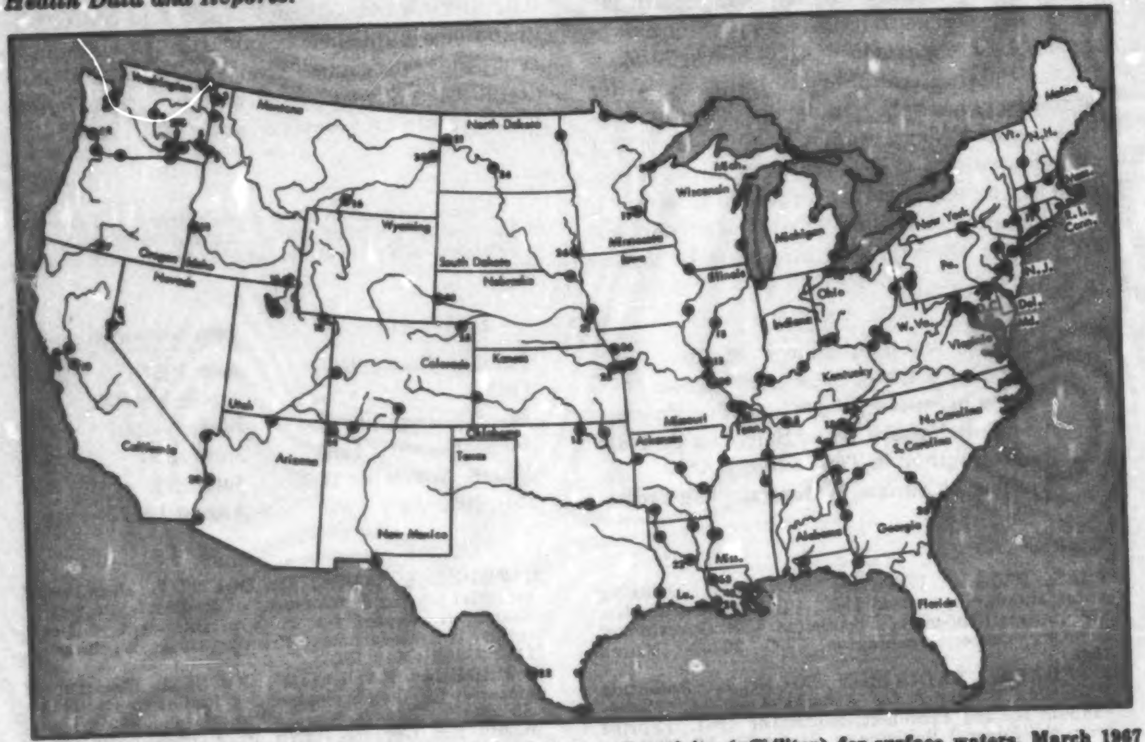
Washington
Montana
North Dakota
Oregon
Idaho
Nevada
Wyoming
South Dakota
Nebraska
Minnesota
Iowa
Wisconsin
Mich.
Michigan
Illinois
Indiana
Ohio
New York
Pa.
N.J.
Del.
Md.
W. Va.
Virginia
Kentucky
Tenn.
N. Carolina
S. Carolina
Georgia
Alabama
Miss.
La.
Florida
Arkansas
Missouri
Kansas
Colorado
Utah
Arizona
California
New Mexico
Texas
Oklahoma
Maine
Vt.
N.H.
Mass.
R.I.
Conn.

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) for surface waters, March 1967

Table 1. Radioactivity in raw surface waters, March 1967

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	1	1	2	5	7	12
Arkansas River:						
Ponca City, Okla.	0	7	7	3	18	21
Atchafalaya River:						
Morgan City, La.	11	< 1	11	41	7	48
Bear River:						
Preston, Idaho	0	2	2	1	16	17
Big Horn River:						
Hardin, Mont.	0	10	10	3	25	28
Big Sioux River:						
Sioux Falls, S. Dak.	< 1	2	2	3	27	30
Clearwater River:						
Lewiston, Idaho	0	< 1	< 1	1	3	4
Clinch River:						
Clinton, Tenn.	2	0	2	8	3	11
Kingston, Tenn.ᵃ	0	0	0	0	16	16
Colorado River:						
Loma, Colo.	3	7	10	12	47	59
Page, Ariz.	0	5	5	1	29	30
Parker Dam, Calif.-Ariz.	0	0	0	0	19	19
Columbia River:						
Wenatchee, Wash.	0	0	0	0	4	4
Pasco, Wash.ᵃ	0	1	1	30	315	345
Clatskanie, Ore.	0	< 1	< 1	20	61	81
Connecticut River:						
Enfield Dam, Conn.	0	0	0	1	4	5
Coosa River:						
Rome, Ga.	< 1	1	1	2	3	5
Cumberland River:						
Cheatham Lock, Tenn.	0	0	0	1	3	4
Delaware River:						
Philadelphia, Pa.	1	0	1	3	7	10
Great Lakes:						
Duluth, Minn.	0	0	0	0	2	2
Detroit, Mich.	0	0	0	0	4	4
Green River:						
Dutch John, Utah	0	3	3	< 1	13	13
Hudson River:						
Poughkeepsie, N.Y.	0	0	0	1	6	7
Illinois River:						
Peoria, Ill.	1	2	3	4	10	14
Grafton, Ill.	0	3	3	2	11	13
Kansas River:						
DeSoto, Kans.	0	1	1	1	18	19
Klamath River:						
Keno, Ore.	< 1	0	< 1	2	7	9
Maumee River:						
Toledo, Ohio	0	1	1	5	7	12
Mississippi River:						
St. Paul, Minn.	0	1	1	1	11	12
E. St. Louis, Ill.	1	1	2	5	9	14
New Roads, La.	2	0	2	8	7	15
New Orleans, La.	3	1	4	7	7	14
Missouri River:						
Williston, N. Dak.	0	4	4	3	14	17
Bismarck, N. Dak.	1	3	4	6	16	22
St. Joseph, Mo.	2	4	6	7	17	24
North Platte River:						
Henry, Nebr.	0	27	27	2	34	36
Ohio River:						
Cairo, Ill.	3	0	3	22	6	28
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	1	1	1	4	5
Platte River:						
Plattsmouth, Nebr.	4	7	11	22	23	45
Potomac River:						
Washington, D.C.	1	0	1	1	3	4
Red River, North:						
Grand Forks, N. Dak.	0	0	0	0	19	19
Red River, South:						
Alexandria, La.	0	0	0	2	7	9
Rio Grande:						
El Paso, Tex.	51	2	53	205	16	221
Laredo, Tex.	1	8	9	4	14	18
San Joaquin River:						
Vernalis, Calif.	0	1	1	1	4	5
San Juan River:						
Shiprock, N. Mex.	4	2	6	13	8	21
Savannah River:						
Port Wentworth, Ga.ᵃ	0	0	0	2	12	14
Snake River:						
Payette, Idaho	0	4	4	1	13	14
Wawawai, Wash.	0	1	1	1	6	7
South Platte River:						
Julesburg, Colo.	2	30	32	11	45	56
Susquehanna River:						
Conowingo, Md.	0	0	0	0	5	5
Tennessee River:						
Chattanooga, Tenn.	< 1	1	1	2	5	7
Yellowstone River:						
Sidney, Mont.	4	7	11	22	15	37
Maximum	51	30	53	205	315	345
Minimum	0	0	0	0	2	2

ᵃ Gross beta radioactivity at this station may not be directl ycomparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides common to all stations.

average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both February and March 1967, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved solids:

North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.

During March, both the alpha radioactivity and the beta radioactivity on suspended solids exceeded 15 pCi/liter and 150 pCi/liter, respectively, at El Paso, Tex., on the Rio Grande. Pasco, Wash., on the Columbia River continued to show beta radioactivity on dissolved solids in excess of 150 pCi/liter.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(*2*) *Ibid.*, 1959 Edition.
(*3*) *Ibid.*, 1960 Edition.
(*4*) *Ibid.*, 1961 Edition.
(*5*) *Ibid.*, 1962 Edition.
(*6*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Radioactivity in New York Surface Water, January-December 1966

Division of General Engineering
and Radiological Health
State of New York Department of Health

In 1965, the New York State Department of Health began a program to determine the amount of radioactivity in water used for public consumption. Radioactivity in water may arise from any one or a combination of the following sources: the natural mineral content of water (background), atmospheric fallout, or nuclear industry operations. Water samples are obtained from 45 locations for gross beta-particle analysis (figure 1). Table 1 gives the sampling frequency and type of sample. Larger size samples are collected at selected locations for strontium–90 analysis.

Analytical procedures

Strontium and other alkaline earths are precipitated as carbonates from a 500 ml sample. Iron and rare earths are removed by hydroxide scavenging, while barium is precipitated as a chromate. Strontium is finally precipitated as a sulfate from a pH controlled EDTA solution. Calcium and yttrium remain in solution as EDTA complexes (*1, 2*).

Strontium–90 is determined by yttrium–90 in-growth counting of the final precipitate at less than 6 hours after precipitation and again at greater than 50 hours using a low background (less than 1 cpm) gas flow, proportional beta-particle counter. Strontium–89 is estimated by taking the difference between the total strontium and the strontium–90 radioactivity.

Chemical recovery is between 70 and 75 percent and results in a minimum detectable radioactivity of 3 pCi/liter ± 100 percent at the 95-percent confidence level.

Discussion and results

The observed gross beta-particle concentrations in New York surface water for January–December 1966 are given in table 1. It should be noted that the Cohoes gross beta-particle results are for a raw water sample, while the Cohoes radiostrontium results are for a finished water sample.

The average concentrations of strontium–89 and strontium–90 in New York water for Jan-

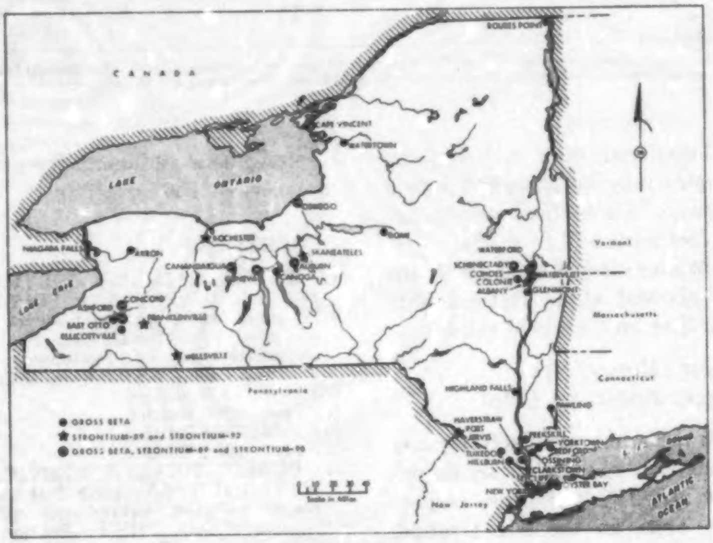
CANADA
LAKE ONTARIO
LAKE ERIE
ROUSES POINT
CAPE VINCENT
WATERTOWN
OSWEGO
ROME
ROCHESTER
NIAGARA FALLS
AKRON
SKANEATELES
CANANDAIGUA
GENEVA
AUBURN
CANOGA
WATERFORD
SCHENECTADY
COHOES
COLONIE
ALBANY
WATERVLIET
GLENMONT
CONCORD
ASHFORD
EAST OTTO
ELLICOTTVILLE
FRANKLINVILLE
WELLSVILLE
Vermont
Massachusetts
Connecticut
Pennsylvania
HIGHLAND FALLS
PAWLING
HAVERSTRAW
PORT JERVIS
PEEKSKILL
YORKTOWN
BEDFORD
TUXEDO
HILLBURN
OSSINING
CLARKSTOWN
OYSTER BAY
NEW YORK
New Jersey
ATLANTIC OCEAN
● GROSS BETA
★ STRONTIUM-89 and STRONTIUM-90
● GROSS BETA, STRONTIUM-89 and STRONTIUM-90
Scale in Miles

Figure 1. New York water sampling locations

Table 1. Gross beta radioactivity in New York raw surface water, January–December 1966

Location	Sampling	Concentration (pCi/liter) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Akron (Murder Creek)	BW	9	9	9	----	6	6	6	5	3	6	6	7
Ashford (Buttermilk Creek at Fox Valley Bridge)	SA	1	2										
(Cattaraugus Creek at Bigelow Bridge)	SA	2	2										
(Buttermilk Creek at Thomas Corners)	SA	3	5										
(West Valley W.S. Reservoir)	SA	----	6										
Auburn (Owasco Lake)	SA	----	----	----	----	----	4	----	----	----	3		
Bedford (Byram Lake)	M	----	----	7	----	7							
Canandaigua (Canandaigua Lake)	SA	5	----	----	----	----	6	----	----	----	4		
Canoga (Cayuga Lake)	SA	----	----	----	----	----	----	----	----	----	5		
Cape Vincent (Black River)	SA	5											
(St. Lawrence River)	SA	----	----	----	----	----	4						
Clarkstown (Congers Lake)	Q	----	----	----	----	----	6	----	10				
(Lake De Forest)	Q	----	----	----	----	----	6	----	5				
Cohoes (Mohawk River)	D	4	4	6	2	3	4	5	2	4	6	3	4
Colonie (Patroon Creek)	SA	----	----	----	----	----	----	10	----	----	----	6	
Concord (18 Mile Creek)	SA	----	3										
(Cattaraugus Creek at Sooby Hill Bridge)	SA	----	4										
East Otto (East Otto Creek)	SA	----	3										
(Connoisarauley Creek)	SA	----	2										
Ellicottville (Beaver Meadow Creek)	SA	2	3										
Farmersville (Ischua Creek)	SA	3	3										
Geneva (Seneca Lake)	SA	----	----	----	----	4	----	----	----	----	3		
Glenmont (Hudson River)	D	3	6	6	3	3	4	5	5	4	3	4	6
Haverstraw (Letchworth Village River)	Q	----	----	----	----	2	3	----	2	----	2		
Highland Falls (Bog Meadow Brook)	M	2	----	3	----	3	4	4	2	4	----	3	2
Hillburn (Hillburn Reservoir)	Q	----	----	----	----	8	2	----	7	----	< 1		
Lansing (Airport Well)	SA	----	----	----	----	----	< 1						
(Kahre Well)	SA	----	----	----	----	----	< 1						
(Shively Well)	SA	----	----	----	----	----	< 1						
(Tracey Tobey)	SA	----	----	----	----	----	< 1						
(General Electric)	SA	----	----	----	----	----	< 1						
(Buttermilk Creek)	SA	----	----	----	----	----	----	----	----	----	----	----	4
New York City	SA	----	----	5									
Niagara Falls (East Branch-Niagara River)	Q	----	----	----	----	----	----	----	4	----	----	5	
(West Branch-Niagara River)	Q	----	----	----	----	----	----	----	3	4	----	3	
Orangetown (Hackensack River)	SA	----	----	----	----	7							
Ossining (Hudson River)	D	15	17	8	6	< 1	16	34	30	53	34	15	25
(Indian Brook Reservoir)	M	----	< 1	5	----	----	4	6	6	5	----	5	4
Oswego (Lake Ontario)	M	----	----	----	----	----	----	----	----	----	6	5	
(Oswego River)	Q	----	----	----	----	4	6	----	3	----	6		
Oyster Bay (Lake Ontario)	SA	----	4	----	----	----	----	----	----	5			
Pawling (Pond at United Nuclear)	M	----	----	----	----	----	5	2	3	5	----	4	
Peekskill (Camp Field Water Supply)	M	4	< 1	3	< 1	2	< 1	----	< 1	7	14	3	5
(Hudson River)	D	12	6	3	10	4	17	24	29	36	18	15	15
Rome (Fish Creek)	BW	3	----	----	----	----	----	----	3	3	----	4	3
Rouses Point (Lake Champlain)	Q	----	----	----	----	----	----	5					
Schenectady (Mohawk River)	C	4	4	5	----	5	4	4	3	3	3	4	3
Tuxedo (Indian Kill)	M	3	----	3	----	----	4	----	3	4	----	4	
Waterford (Hudson River)	C	2	3	5	----	6	4	4	4	5	2	2	
Watertown (Black River)	BW	----	5	4	4	5	4	4	4	4	4	4	4
Watervliet (French Mills Reservoir)	BW	4	4	4	----	4	4	3	3	3	4	3	4
Yorktown (Croton Reservoir)	M	----	----	2	----	----	3	5	5	3	----	4	4

BW, biweekly composite of daily grab samples.
D, weekly composite of daily grab samples.
C, continuous bleed-off-analyzed weekly.
NS, no sample collected.
M, monthly grab sample.
Q, quarterly grab sample.
SA, semiannual grab sample.

uary through November 7, 1966, were less than the level of detectability except for those stations listed in table 2.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	June 1966

REFERENCES

(1) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Determinations of strontium-90 in milk by ion exchange method. Anal Chem 33:1306–1308 (September 1961).

(2) WELFORD, G. and D. SUTTON. A paper presented at the American Chemical Society meeting in New York City (September 1960).

Table 2. Strontium-89 and strontium-90 in New York surface waters, January-November 7, 1966[a]

Location	Date 1966	Concentration (pCi/liter) Strontium-89	Strontium-90
Ashford (Cattaraugus Creek at Bigelow Bridge)	3/15	8	< 3
Cohoes (Mohawk River)	1/10–17	11	< 3
Concord[b] (Springville Power Dam on Cattaraugus Creek)	10/11–13	< 3	78
	10/14	69	174
	10/20–21	< 3	57
	10/27–28	65	265
	11/1–2	76	256
	11/2–3	73	234
	11/4–7	19	58

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[a] All results for all stations, except for those listed, were below the detectable levels of 3 pCi/liter for strontium-89 and strontium-90.

[b] These samples were collected from a sampling station located downstream from the Nuclear Fuel Services spent fuel processing plant located in Cattaraugus County.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta-particle analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from programs of the U. S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
HASL Fallout Network	July–December 1965	March 1967
HASL 80th Meridian Network	Calendar Year 1965	January 1967
National Air Sampling Network (discontinued measurement)	October–December and annual summary 1966	April 1967
Plutonium in Airborne Particulates	October–December 1966	May 1967

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1. Radiation Surveillance Network
May 1967

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Md., for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity made by the station operators. These estimates are made after the decay of radon and thoron daughter products and prior to submission of the samples for laboratory analysis. When high airborne radioactivity levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during May 1967. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2.

Gross beta radioactivity in air and precipitation continued to be near or below detectable levels. No indication of fresh fission products was found on any of the samples analyzed in May 1967.

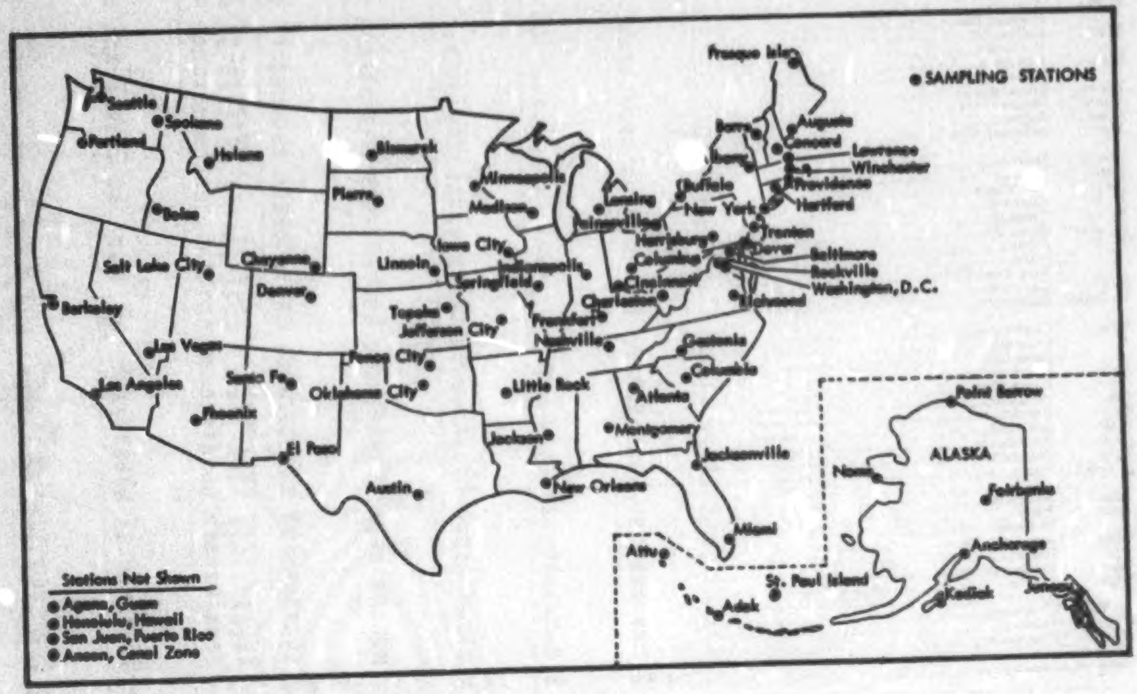
● SAMPLING STATIONS
Presque Isle
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Lansing
Painesville
Buffalo
Barre
Albany
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
New York
Trenton
Harrisburg
Dover
Baltimore
Rockville
Washington, D.C.
Columbus
Cincinnati
Charleston
Richmond
Salt Lake City
Cheyenne
Denver
Lincoln
Iowa City
Indianapolis
Springfield
Berkeley
Topeka
Jefferson City
Frankfort
Nashville
Las Vegas
Ponca City
Santa Fe
Oklahoma City
Little Rock
Gastonia
Columbia
Atlanta
Los Angeles
Phoenix
Montgomery
El Paso
Jackson
Jacksonville
Austin
New Orleans
Miami
Point Barrow
ALASKA
Nome
Fairbanks
Anchorage
Attu
St. Paul Island
Adak
Kodiak
Juneau
Stations Not Shown
● Agana, Guam
● Honolulu, Hawaii
● San Juan, Puerto Rico
● Ancon, Canal Zone

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, May 1967

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	31	7	0.25	0.00	0.06	Nov 66	127	<25
Alaska:	Adak	31		.11	.00	.03	June 67	(b)	
	Anchorage	21	3	.12	.01	.06	Dec 66	12	< 2
	Attu Island	31		.05	.00	.01	July 67	(b)	
	Fairbanks	(c)					Jan 67	(b)	
	Juneau	16	10	.15	.00	.04	Apr 67	145	<29
	Kodiak	2		.04	.03	.04	May 67	(b)	
	Nome	1		.02	.02	.02	Sept 67	(b)	
	Pt. Barrow	30		.14	.01	.04	Aug 67	(b)	
	St. Paul Island	(c)					Oct 66	(b)	
Ariz:	Phoenix	26		.19	.05	.11	Apr 67	(b)	
Ark:	Little Rock	28	10	.11	.01	.06	Dec 66	317	<63
Calif:	Berkeley	24		.17	.03	.09	May 67	(b)	
	Los Angeles	24	1	.12	.03	.07	Sept 67	2	< 1
C.Z:	Ancon	10		.04	.01	.02	May 67	(b)	
Colo:	Denver	31	6	.13	.01	.06	May 67	74	<15
Conn:	Hartford	31	11	.20	.00	.07	Apr 67	99	<20
Del:	Dover	22		.18	.03	.06	Nov 66	(b)	
D. C:	Washington	30	16	.18	.03	.07	Aug 67	97	<20
Fla:	Jacksonville	30	4	.18	.00	.06	Dec 66	41	< 8
	Miami	28	3	.21	.03	.06	Apr 67	29	< 6
Ga:	Atlanta	31	6	.23	.03	.09	Oct 66	83	<17
Guam:	Agana	30		.04	.00	.01	Nov 66	(b)	
Hawaii:	Honolulu	31	2	.07	.01	.03	July 67	65	<13
Idaho:	Boise	30	4	.11	.02	.07	July 67	11	< 2
Ill:	Springfield	28	6	.17	.01	.06	Aug 67	135	<27
Ind:	Indianapolis	29	14	.16	.01	.06	Oct 66	139	<28
Iowa:	Iowa City	31	6	.14	.01	.09	May 67	25	< 5
Kans:	Topeka	31	3	.15	.01	.06	Dec 66	34	< 7
Ky:	Frankfort	27	8	.14	.02	.06	Aug 67	48	<10
La:	New Orleans	29	5	.30	.01	.06	Aug 67	64	<13
Maine:	Augusta	30	10	.12	.00	.05	Sept 67	116	<23
	Presque Isle	23	2	.33	.00	.04	May 67	11	< 2
Md:	Baltimore	22	7	.26	.03	.11	Apr 67	53	<11
	Rockville	15		.16	.04	.08	July 67	(b)	
Mass:	Lawrence	30	9	.14	.01	.07	Nov 66	100	<32
	Winchester	19	8	.13	.01	.07	June 67	103	<21
Mich:	Lansing	30	10	.14	.00	.08	July 67	26	< 5
Minn:	Minneapolis	19	4	.09	.03	.07	Nov 66	30	< 6
Miss:	Jackson	28	7	.13	.01	.06	Sept 67	205	<41
Mo:	Jefferson City	31	12	.14	.01	.06	Oct 66	129	<26
Mont:	Helena	29	7	.16	.01	.08	June 67	43	< 9
Nebr:	Lincoln	19	6	.12	.01	.06	Oct 66	100	<20
Nev:	Las Vegas	25		.17	.03	.06	Jan 67	(b)	
N. H:	Concord	21		.18	.01	.08	Aug 67	(b)	
N. J:	Trenton	31	6	.14	.01	.07	Sept 67	18	< 4
N. Mex:	Santa Fe	29	2	.14	.02	.05	June 67	6	< 1
N. Y:	Albany	22	6	.18	.00	.08	Oct 66	69	<14
	Buffalo	24		.12	.03	.07	May 67	(b)	
	New York City	30		.15	.02	.07	June 67	(b)	
N. C:	Gastonia	31	11	.23	.02	.09	May 67	135	<27
N. Dak:	Bismarck	30	3	.13	.03	.07	Aug 67	22	< 5
Ohio:	Cincinnati	20		.18	.03	.09	Nov 66	(b)	
	Columbus	28	11	.21	.04	.10	Sept 67	120	<26
	Painesville	29	12	.15	.03	.09	Apr 67	90	<18
Okla:	Oklahoma City	31	6	.20	.01	.06	July 67	89	<18
	Ponca City	26	5	.09	.00	.03	Apr 67	46	< 9
Ore:	Portland	31	7	.11	.01	.03	Oct 66	33	< 7
Pa:	Harrisburg	30	2	.13	.02	.06	Oct 66	81	<16
P.R:	San Juan	26	6	.20	.01	.07	Sept 67	80	<16
R. I:	Providence	30	10	.14	.00	.08	July 67	183	<37
S. C:	Columbia	24	10	.18	.01	.07	June 67	162	<33
S. Dak:	Pierre	31	3	.13	.01	.08	Apr 67	30	< 6
Tenn:	Nashville	31	10	.13	.01	.05	July 67	147	<29
Tex:	Austin	30	6	.14	.02	.06	Nov 66	68	<14
	El Paso	31	1	.22	.01	.09	Aug 67	2	< 1
Utah:	Salt Lake City	30	13	.18	.02	.10	Sept 67	55	<11
Vt:	Barre	30	15	.17	.01	.07	Dec 66	127	<26
Va:	Richmond	29	9	.17	.01	.08	Dec 66	57	<12
Wash:	Seattle	31	6	.09	.01	.05	Dec 66	12	< 3
	Spokane	31	4	.12	.01	.07	Nov 66	39	< 8
W. Va:	Charleston	29	17	.18	.01	.07	June 67	154	<31
Wis:	Madison	31	9	.26	.02	.07	Dec 66	102	<21
Wyo:	Cheyenne	31	13	.13	.01	.06	Jan 67	108	<21
Network summary		1,930	400	0.33	0.00	0.06		83	<16

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[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of less than 0.005 are reported and used in averaging as 0.00 pCi/m³.

[b] No precipitation sample collected.

[c] No report received.

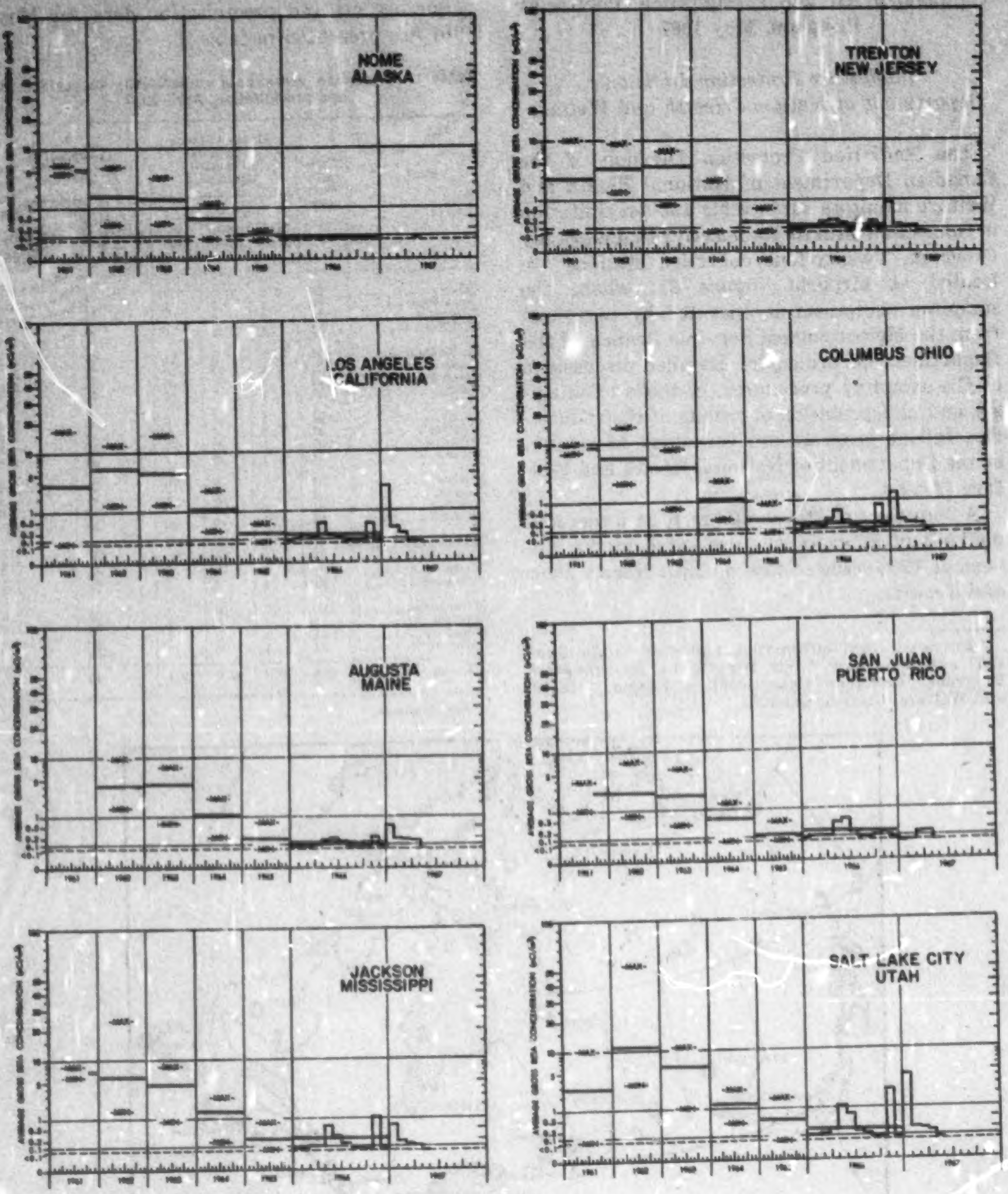

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Surveillance Network, 1961–May 1967

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2. Canadian Air and Precipitation Monitoring Program, May 1967[1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for May 1967 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, April 1967

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	28	0.2	0.0	0.1	31	1.0
Coral Harbour	30	.1	.0	.0	11	0.2
Edmonton	31	.2	.0	.1	62	1.0
Ft. Churchill	31	.1	.0	.0	33	0.7
Ft. William	31	.1	.0	.1	41	1.2
Fredericton	31	.1	.0	.0	12	2.0
Goose Bay	31	.1	.0	.0	16	0.7
Halifax	31	.1	.0	.0	16	2.7
Inuvik	31	.1	.0	.0	32	1.0
Montreal	31	.2	.0	.1	32	1.9
Moosonee	31	.1	.0	.1	30	.8
Ottawa	31	.1	.0	.1	34	1.3
Quebec	31	.1	.0	.0	20	1.0
Regina	31	.2	.0	.1	147	1.2
Resolute	31	.1	.0	.0	NS	NS
St. John's, Nfld.	31	.1	.0	.0	16	2.1
Saskatoon	31	.2	.0	.1	91	1.9
Saulte Ste Marie	31	.1	.0	.1	33	2.1
Toronto	31	.2	.0	.1	29	1.7
Vancouver	31	.1	.0	.0	28	1.0
Whitehorse	31	.2	.0	.1	31	.9
Windsor	29	.1	.0	.1	32	1.4
Winnipeg	31	.1	.0	.1	10	.3
Yellowknife	31	.1	.0	.1	224	2.0
Network summary	738	0.2	0.0	0.1	43	1.5

NS, no sample.

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[1] Prepared from information and data in the June 1967 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

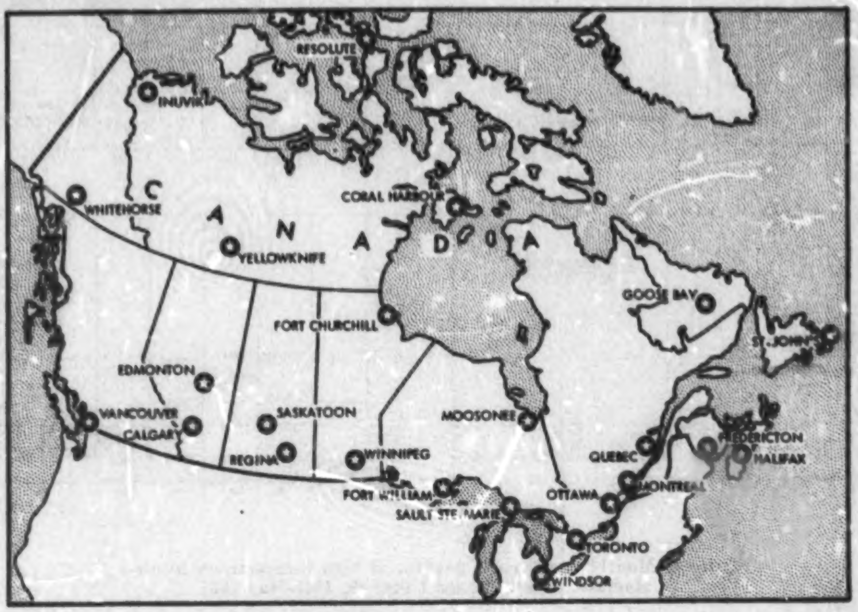
RESOLUTE
INUVIK
WHITEHORSE
C A N A D A
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
ST. JOHN'S
FORT CHURCHILL
EDMONTON
SASKATOON
VANCOUVER
CALGARY
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
SAULT STE. MARIE
OTTAWA
MONTREAL
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

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3. Mexican Air Monitoring Program
May 1967

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of eight samples per month were needed to get a reliable average radioactivity at each station (7).

The maximum, minimum, and average beta-particle concentrations in surface air during May 1967 are presented in table 4.

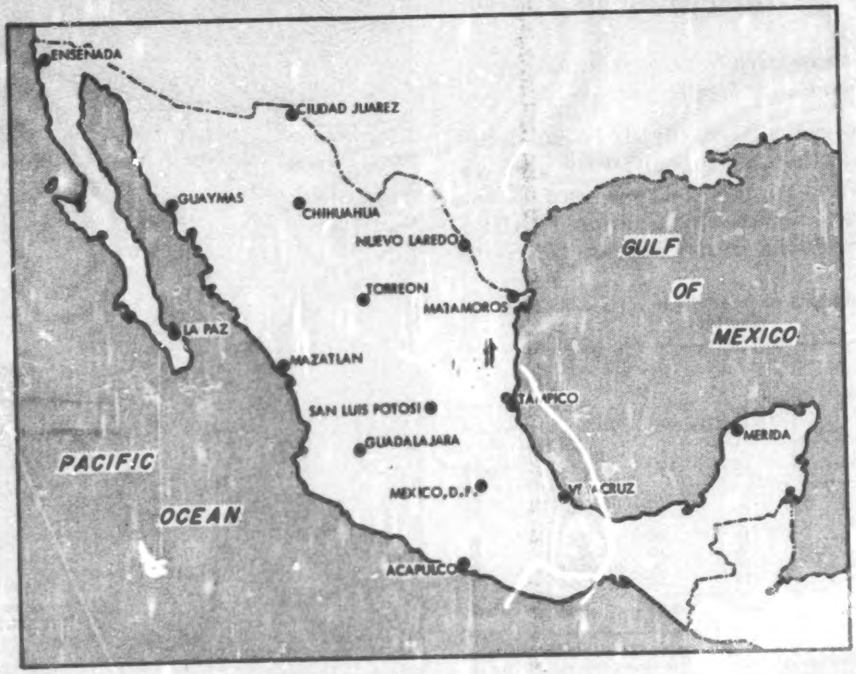

Figure 4. Mexican air sampling locations

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Table 4. Mexican gross beta radioactivity of airborne particulates May 1967

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	15	0.1	0.1	0.1
Chihuahua	15	.2	< .1	.1
Ciudad Juáres	12	.2	< .1	.1
Ensenada	5	.2	< .1	(a)
Guadalajara	NS			
Guaymas	NS			
La Paz	11	.2	< .1	.1
Matamoros	NS			
Mazatlán	16	.3	.1	.1
Mérida	10	.1	.1	.1
México, D. F	10	.1	< .1	.1
Neuvo Laredo	4	.3	.1	(a)
San Luis Potosí	NS			
Tampico	4	.1	< .1	(a)
Torreon	11	.1	< .1	.1
Veracrus	17	.2	< .1	.1

[a] An average is not presented for any station presenting less than 7 samples.
NS, indicates no sample collected, station temporarily shutdown.

4. Pan American Air Sampling Program May 1967

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U. S. Public Health Service (PHS) to

Table 5. Gross beta radioactivity in surface air, PAHO May 1967

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	18	0.06	0.01	0.03
Bolivia: La Paz	(b)			
Chile: Santiago	30	.05	.00	.02
Colombia: Bogota	19	.01	.00	.01
Ecuador: Guayaquil	(b)			
Jamaica: Kingston	16	.08	.02	.03
Peru: Lima	23	.03	.00	.02
Venezuela: Caracas	19	.04	.01	.02
West Indies: Trinidad	18	.05	.02	.03
Pan American summary	143	0.08	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
[b] No sample collected.

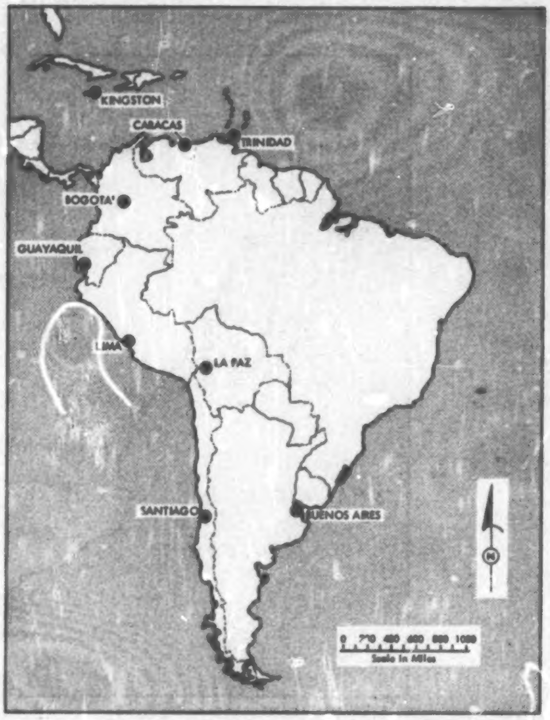

Figure 5. Pan American Air Sampling Program stations

assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station positions are shown in figure 5.

The May 1967 air monitoring results from the participating countries are given in table 5.

5. Fallout in the United States and Other Areas July–December 1966[1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Monthly fallout deposition rates for strontium–90 are determined by the Health and Safety Laboratory (HASL) for 49 sites in the United States and 107 locations in other countries. HASL data from all of the active U.S. stations and other selected points in the Western Hemisphere (figure 6) covering the period from July through December 1966, are summarized in tables 6 and 7. All the stations of the 80th Meridian Network are represented.

Methods of collection

Two methods of fallout collection are employed by HASL. In the first, precipitation and dry fallout are collected for a period of 1 month in a stainless-steel pot with an exposed area of 0.076 m². At the end of the collection period, the contents are transferred, by careful scrubbing with a rubber spatula, to a polyethylene sample bottle which is then shipped to the laboratory for analysis.

The second method involves the use of a polyethylene funnel, with an exposed area of

Table 6. Strontium-90 fallout in the United States, HASL, July-December 1966

Sampling location		Type of collection	Deposition (nCi/m²)					
			July	Aug	Sept	Oct	Nov	Dec
Ala:	Birmingham	pot	0.13	0.22	0.12	0.03	0.06	0.05
Alaska:	Anchorage	column	.04	.10	.06	.01	.02	NS
	Barrow	column	.18	.04	.02	.01	.03	NS
	Cold Bay	column	.09	.15	.07	.04	.08	.10
	Fairbanks	column	.09	.06	T	.02	.04	.01
	Juneau	column	.12	.13	.26	.13	.03	NS
	Nome	column	.08	T	T	NS	NS	NS
Calif:	W. Los Angeles	pot	.03	T	.01	T	.05	.06
	San Francisco	column	.01	T	T	.01	.01	.06
Colo:	Denver	column	.50	.07	.08	.03	.09	.03
Fla:	Coral Gables	pot	.10	.07	NS	NS	NS	NS
	Miami	column	.23	.16	.05	.05	.07	NS
Hawaii:	Hilo	column	.46	.15	.09	.18	.13	NS
	Honolulu	pot	.03	.08	.07	.08	.36	.09
	Lihue	column	.08	.05	.02	.08	.06	NS
	Mauna Loa	column	.02	T	.01	.06	.02	NS
Ill:	Argonne	pot	.08	.06	.03	.05	.10	.07
La:	New Orleans	column	.20	.08	.07	.03	.03	NS
Minn:	International Falls	column	.08	.18	.05	.03	.03	NS
Mo:	Columbia	column	.07	.03	.09	.06	.06	.04
Mont:	Helena	column	.11	.06	.05	.04	.05	.04
N.J:	Westwood	pot	.15	.05	.12	.03	.08	.06
N.Y:	New York City	pot	.09	.12	.22	.08	.08	.10
N. Dak:	Williston	column	.19	.12	.05	.03	.01	NS
Ohio:	Wooster	pot	.14	.09	.04	.04	.03	.03
Okla:	Tulsa	pot	.07	.14	.06	.03	.01	.07
Ore:	Medford	column	.07	.06	.04	.04	.02	NS
S.C:	Columbia	column	.12	.08	.04	.07	.04	.07
S. Dak:	Vermillion	pot	.35	.20	.16	.10	.02	NS
Tex:	Dallas	column	.09	.10	.04	.02	.02	.04
	El Paso	column	.03	.07	.03	.02	.01	NS
	Houston	column	.07	.08	.05	.04	.04	NS
Utah:	Salt Lake City	pot	.09	.06	.14	.06	.07	.06
Va:	Sterling	column	.09	.04	.10	.04	.04	NS
Wash:	Seattle	pot	.12	.02	.08	.06	NS	NS
	Seattle	pot	.15	.03	.08	.06	.16	.16
	Forks [a]	column	.10	NS	NS	NS	NS	NS
Wis:	Green Bay	column	.23	.22	.04	.02	.06	.05

[a] Sampler located on Tatoosh Island until August 1966.
T zero or trace.
NS, no sample reported.

1.80

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[1] The data in this article compiled from "Fallout Program Quarterly Summary Report," HASL 182:A-1 to A-169; B-1 to B-22.

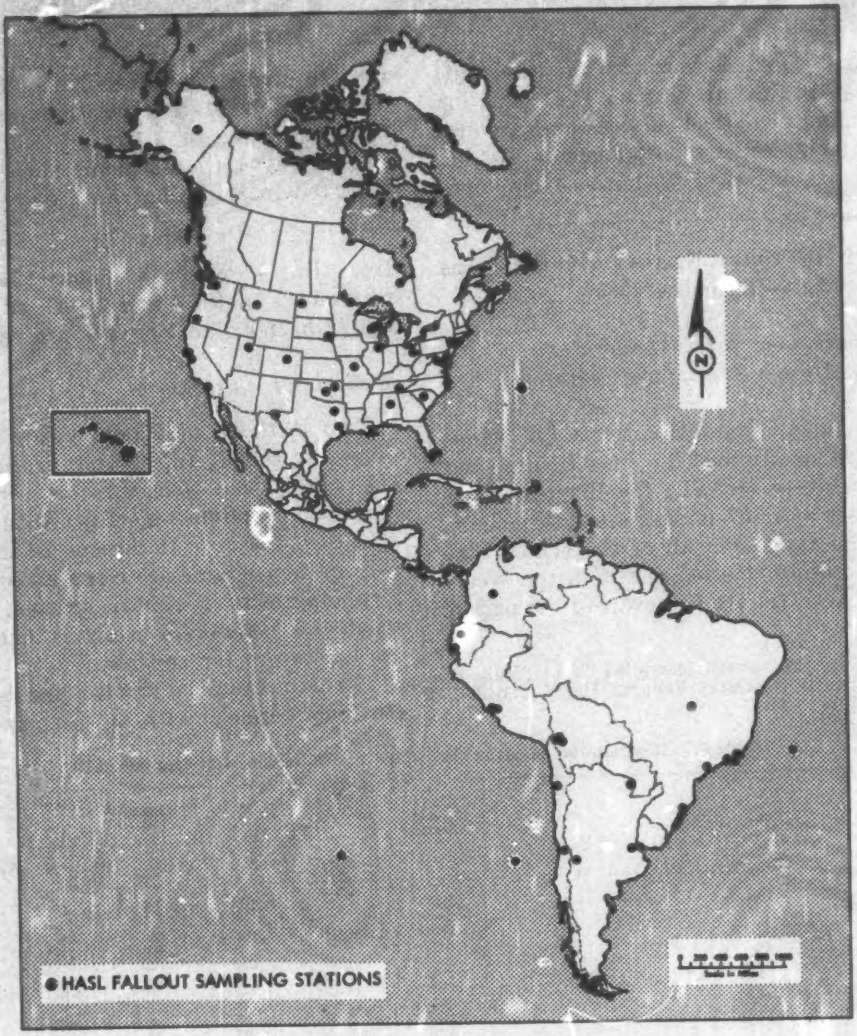

Figure 6. HASL fallout sampling stations in the Western Hemisphere

0.072 m², attached to an ion exchange column. After a 1-month collection, the inside of the funnel is wiped with a tissue, and the tissue is inserted in the end of the column, which is then sealed and sent to HASL for analysis. It has been shown that at the 95-percent confidence level there was no significant difference in the strontium-90 measurements obtained from samples collected by the two methods (*1*).

Other radionuclides

Laboratories at Westwood, N.Y., New York City, N.Y., and Seattle, Wash., have analyzed monthly precipitation samples for various radionuclides. The amount of precipitation at each station and the monthly deposition rates for iron-55, strontium-90, cerium-144, plutonium-238, and plutonium-239-240, at each station are presented in table 8.

Table 7. Strontium-90 fallout in North and South America, HASL, July-December 1966

Sampling location		Type of collection	Deposition (mCi/m²) July	Aug	Sept	Oct	Nov	Dec
Argentina:	Buenos Aires	column	0.02	T	0.05	0.44	0.35	NS
	Formosa	column	.02	T	.05	.26	.13	NS
	Malargue	cloumn	.05	T	.04	.04	.12	NS
Bahamas:	Bimini	column	.06	0.12	.10	NS	.04	0.05
Bermuda:	Kindley AFB	column	.14	.05	.08	.06	.07	.06
Bolivia:	Chacaltaya	column	NS	NS	NS	NS	NS	NS
	La Paz (city	column	NS	NS	NS	NS	NS	NS
	La Paz (Ovejuyo)	column	NS	NS	NS	NS	NS	NS
Brasil:	Belem	column	.05	.02	.03	.24	.06	NS
	Brasilia	pot	NS	NS	NS	NS	NS	NS
	Itaici Sao Paulo	pot	.04	.06	NS	.16	NS	NS
	Nova Friburgo	pot	.05	.15	.08	.28	NS	NS
	Rio de Janeiro	column	.09	.23	.20	.36	NS	NS
	San Jose Dos Campos	pot	.02	.07	.10	NS	NS	NS
	Sao Leopoldo	pot	.12	.14	.07	.06	NS	NS
	Trindade Island	column	NS	NS	NS	.32	NS	NS
Canada:	Moosonee	column	.12	.03	.03	.01	NS	NS
	Newfoundland [b]	column						
Canal Zone:	Balboa [c]	column	.02	T	T	.02	.04	.08
Chile:	Antofagasta	column	.01	NS	.01	.01	.01	.01
	I. Alejandro Selkirk [d]	column	NS	.11	.11	.08	.08	NS
	Easter Island	column	.06	.05	.09	.07	.24	NS
	Puerto Montt	column	.24	.11	.23	.14	.11	NS
	Punta Arenas	column	T	.02	.06	.03	.04	NS
	Santiago	pot	.04	.01	.01	.04	.02	NS
	Santiago	column	.03	.06	NS	.09	.01	.01
Colombia:	Bogota	pot	T	T	T	NS	NS	NS
Costa Rica:	Turrialba	column	.01	NS	.02	.06	.05	NS
Equador:	Guayaquil	column	.01	.05	NS	.01	.02	NS
	Quito	column	.01	T	T	.01	T	.01
Greenland:	Thule	column	.04	.12	.03	.02	.01	NS
Iceland:	Keflavik	column	.17	.14	.12	.03	.09	.08
Mexico:	Mexico City	column	.09	.09	.02	.02	.01	.01
Peru:	Lima	column	.01	[a].01	[a].01	.04	.05	.03
	Lima	column	.01	.03	.03	.12	.03	NS
Puerto Rico:	San Juan	column	.10	.06	.07	.03	.04	.06
Venezuela:	Caracas (site 1)	column	.06	.02	.02	.03	.02	.08
	Caracas (site 2)	column	[a].03	[a].02	.02	.01	.03	NS

[a] Indicates proportioned from originally consolidated data.
NS, no sample reported.
T, zero or trace.
[b] Collections terminated April 1966.
[c] Changed from Miraflores.
[d] Isla Robinson Crusoe.

Table 8. Radiochemical analyses of precipitation samples at 3 U.S. sites, HASL July–December 1966

	July	Aug	Sept	Oct	Nov	Dec
Precipitation (cm)						
New York, New York	3.18	4.80	22.40	11.78	8.81	8.08
Washington, Seattle	2.77	0.25	3.06	6.63	NS	NS
Iron-55 (nCi/m²)						
New Jersey, Westwood	1.72	0.86	0.84	0.36	0.45	0.52
Washington, Seattle	1.03	0.83	1.07	0.96	NS	NS
Strontium-90 (nCi/m²)						
New Jersey, Westwood	0.15	0.05	0.12	0.07	0.06	0.06
New York, New York	0.09	0.12	0.22	0.04	0.08	0.19
Washington, Seattle	0.02	0.08	0.05	NS	NS	NS
Cerium-144 (nCi/m²)						
New Jersey, Westwood	0.18	0.10	NS	NS	NS	NS
Washington, Seattle	0.27	0.11	0.10	0.13	NS	NS
Plutonium-238 (nCi/m²)						
New York, New York	0.00030	0.00027	0.00021	0.00017	NS	NS
Washington, Seattle	<0.0005	0.0004	0.0006	<0.0002	NS	NS
Plutonium-239,240 (nCi/m²)						
New York, New York	0.00249	0.00221	0.00146	0.00176	NS	NS
Washington, Seattle	0.0016	0.0006	0.0019	0.0014	NS	NS

[a] Data suspect.
NS, no sample reported.

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6. Plutonium in Airborne Particulates January–March 1967

National Center for Radiological Health
U.S. Public Health Service

The Radiation Surveillance Network (RSN) of the National Center for Radiological Health, Public Health Service, located at Rockville, Md., is continuing routine analysis for plutonium in airborne particulates. These analyses were initiated during 1965 as part of the mission to establish, maintain, and operate a national surveillance network to measure radioactivity in the environment.

Air filters from 11 RSN stations are analyzed monthly for plutonium. Each daily filter is counted for gross beta radioactivity and for gamma-ray emitters by gamma-ray spectroscopy 4 to 5 days after collection. For plutonium analysis, a monthly composite is made of one-half of each individual sample for each station. Each composite, representing 10,000 to 20,000 cubic meters of air, is analyzed by gamma-ray spectroscopy prior to the plutonium analysis.

Details of the method of collection and radiochemical analyses were presented in an earlier report (*9*). The results for January through March 1967 are presented in table 9.

Table 9. Plutonium in airborne particulates January–March 1967

Sampling location	Plutonium content [a] (pCi/1,000 m^3)		
	January	February	March
N. Y: Buffalo	0.033	0.053	0.052
N. C: Gastonia	.046	.066	.086
Md: Rockville	.033	.053	.055
S. Dak: Pierre	.040	.041	.063
La: New Orleans	.055	.074	.098
Tex: Austin	.058	.053	.092
Colo: Denver	.053	.073	[b] 2.259
Alaska: Anchorage	.104	.078	.087
Ariz: Phoenix	.053	.139	.115
Hawaii: Honolulu	.039	.042	.054
Wash: Seattle	.063	.072	.044

[a] Plutonium includes ^{238}Pu, ^{239}Pu, and ^{240}Pu.

[b] This sample was counted by alpha-particle spectrometry for individual isotopes of plutonium. The approximate isotopic breakdown is 1.85 pCi/1,000 m^3 239–240Pu and 0.41 pCi/1,000 m^3 238Pu.

REFERENCES

(*1*) RADIATION SURVEILLANCE NETWORK. Monthly tabulation of findings. National Center for Radiological Health, Public Health Service, Washington, D.C. 20201 (Distribution by official request).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*4*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*5*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*6*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*7*) VASQUEZ, M., and R. M. DE NULMAN. Estudios sobre la Radioactividad Ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiológica (in press 1966).

(*8*) LOCKHART, Jr., L. B. and R. L. PATTERSON, Jr. Intercalibration of the major North American air monitoring systems. Radiol Health Data 5:12–15 (January 1964).

(*9*) RUSSELL, J., H. LEVINE, and R. SCHNEIDER. Plutonium in airborne particulates. Radiol Health Data Rep 7:483–484 (August 1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological material and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring in the vicinity of nuclear facilities.

Strontium-90 in Human Bone, October-December 1966

National Center for Radiological Health
Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium–90 in measurable amounts has been present in the global environment for more than a decade and major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown

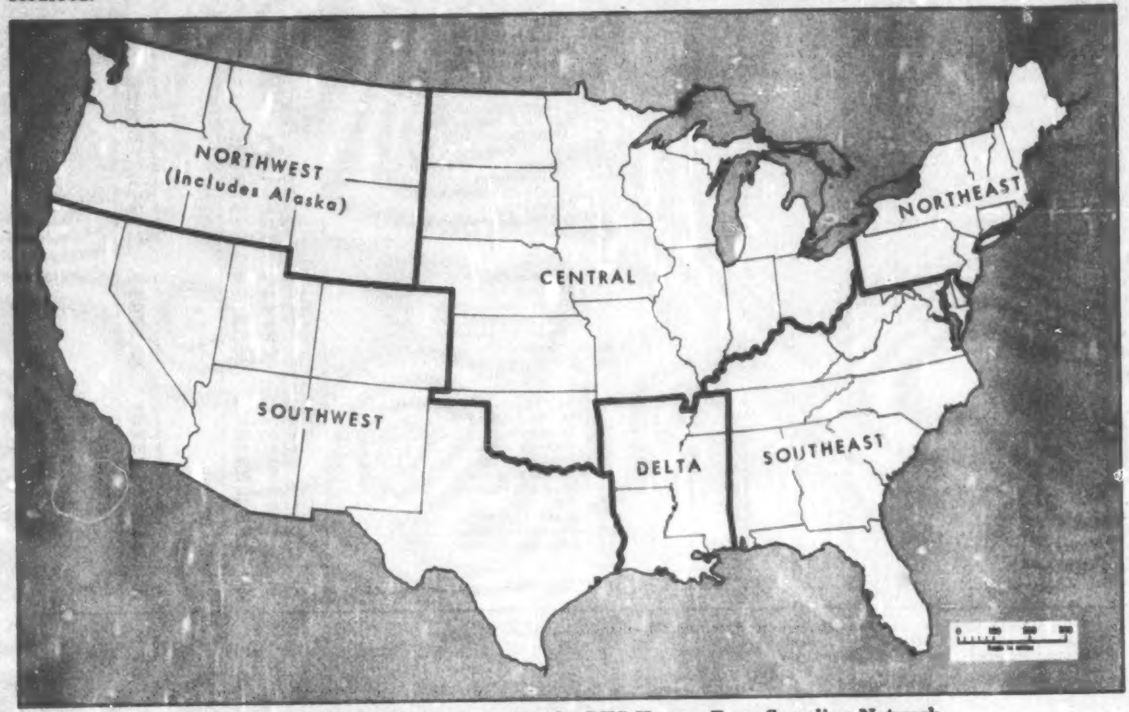

Figure 1. Geographical regions for the PHS Human Bone Sampling Network

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[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, deaths and surgical procedures during October–December 1966

Sampling region and State of residence	Sex	Bone type [a]	Age at death [b] (years)	Cause of death	Strontium-90, pCi/g of:		
					Ash ±2σ error	Calcium	Bone
NORTHEAST:							
N. Y.	M	V	3	Neuroblastoma	0.78 ±0.11	2.20	0.07
Mass.	F	V	4	Leukemia	1.53 ± .19	4.35	.12
N. J.	M	V	4	Acute leukemia	.97 ± .09	2.66	.08
N. Y.	F	V	5	Wilm's tumor	1.21 ± .10	3.30	.12
N. Y.	F	V	6	Acute leukemia	.79 ± .10	2.16	.12
N. H.	M	V	6	Cerebral contusion	1.20 ± .10	3.44	.12
Pa.	M	V	8	Sarcoma of the mesentery	.94 ± .12	[illegible].63	.08
N. Y.	F	V	9	Intracranial hemorrhage	.76 ± .09	2.00	.07
N. Y.	M	V	10	Acute leukemia	1.0[illegible] ± .07	2.97	.12
R. I.	M	V	11	Acute leukemia	1.48 ± .17	4.07	.09
N. H.	M	V	11	Brain tumor	.86 ± .07	2.26	.09
Pa.	M	V	11	Multiple injuries	.68 ± .07	1.85	.07
Mass.	F	V	14	Infectious hepatitis	1.61 ± .10	4.08	.23
N. Y.	M	V	14	Acute leukemia	.96 ± .07	2.52	.13
Pa.	F	V	15	Asphyxiation	.93 ± .07	2.44	.14
N. Y.	M	V	16	Reticulum cell sarcoma	.86 ± .07	2.25	.11
Conn.	M	V,R	18	Subdural hematoma	.73 ± .08	2.12	.12
Pa.	F	V	19	Nephrosclerosis	.81 ± .06	2.14	.13
N. Y.	M	V	19	Acute leukemia	.93 ± .09	2.44	.14
Conn.	M	V,R	20	Head injury	.77 ± .07	1.93	.11
R. I.	F	V,S	21	Brain abscess	.64 ± .06	1.78	.07
N. Y.	F	V	22	Hodgkin's disease	.55 ± .08	1.46	.08
Pa.	F	V	23	Nephrosclerosis	.61 ± .07	1.61	.08
Mass.	M	V	24	Cerebral laceration	.83 ± .06	2.19	.13
Conn.	M	V	24	Laceration of brain	.86 ± .08	2.12	.11
Mass.	M	V	24	Head injury	.82 ± .07	2.22	.09
SOUTHEAST:							
Md.	F	V	2	Digoxin intoxication	2.20 ±0.22	0.48	0.19
Md.	M	V	6	Acute appendicitis	.83 ± .06	2.24	.11
Md.	F	V	10	Craniocerebral injury	.84 ± .09	2.30	.11
Md.	M	V	13	Craniocerebral injury	.99 ± .07	2.73	.12
Md.	M	V	15	Multiple injuries	1.12 ± .10	3.07	.15
Ky.	F	V	16	Biliary atresia	1.36 ± .09	3.87	.11
Md.	M	V	16	Craniocerebral injury	1.67 ± .11	4.36	.23
Md.	M	V	16	Craniocerebral injury	1.07 ± .10	2.95	.16
Md.	M	V	18	Gunshot wound of head	1.02 ± .07	2.69	.15
Md.	F	V	24	Acute myocarditis	.49 ± .05	1.30	.07
CENTRAL:							
Wis.	M	V	0 (10 mo.)	Congenital heart disease	1.19 ±0.16	3.53	0.10
Wis.	M	V	0 (11 mo.)	Acute leukemia	1.19 ± .10	3.52	.10
Ohio	F	V	1	Pneumococcal meningitis	1.57 ± .16	4.41	.14
Ohio	F	V	2	Aplastic anemia	1.33 ± .16	3.71	.11
Wis.	M	V	2	Acute leukemia	.73 ± .10	2.23	.06
Wis.	F	V	4	Congenital heart disease	.96 ± .13	3.11	.08
Ohio	F	V	5	Lymphosarcoma	.83 ± .12	2.40	.07
Ohio	F	V	5	Epidural hemorrhage	2.00 ± .20	6.73	.23
Ohio	M	V	8	Acute leukemia	1.28 ± .09	3.61	.12
Ohio	M	V	9	Encephalomalacia	.88 ± .07	2.49	.09
Ohio	F	V	11	Mediastinal neoplasm	.70 ± .10	1.96	.05
Ohio	M	V	21	Glomerulonephritis	.60 ± .08	1.67	.09
Minn.	F	V	22	Status asthmaticus	.60 ± .06	1.66	.08
Ohio	M	V	22	Head injury	.75 ± .08	2.01	.12
Ohio	F	V	23	Subdural hematoma	.54 ± .06	1.35	.09
Ohio	M	V	23	Cerebral aneurysm	.68 ± .05	1.24	.08
DELTA:							
La.	F	V	4	Acute leukemia	.94 ±0.04	3.09	0.04
La.	M	V,R	12	Monocytic leukemia	.62 ± .09	1.85	.05
La.	M	V	17	Glomerulonephritis	2.38 ± .13	6.46	.28
La.	M	V	19	Epidural hematoma	.78 ± .08	2.09	.11
La.	F	V	22	Cerebellar sarcoma	.42 ± .07	1.11	.05
La.	F	R	23	Preeclampsia	.47 ± .04	1.16	.20
La.	F	V	23	Pelvic peritonitis	.66 ± .07	1.80	.09
NORTHWEST:							
Ore.	M	V	0 (9 mo.)	Sudden unexplained death	1.77 ±0.22	5.45	0.12
Ore.	M	V	1	Smoke inhalation	1.08 ± .12	4.32	.15
Ore.	M	V	11	Drowning	1.13 ± .08	3.24	.10
Ore.	M	V	12	Rupture of aorta	.04 ± .10	1.81	.06
Ore.	F	V	16	Neck fracture	.65 ± .06	1.75	.10
Ore.	M	V	17	Rupture of aorta	.94 ± .07	2.60	.13
Ore.	F	H,F	18	Multiple injuries	.71 ± .05	1.97	.37
Alaska	M	R	18	(c)	1.47 ± .16	3.81	.03
Ore.	M	SK	20	Head injuries	.51 ± .04	1.37	.23
Ore.	M	V	23	Internal injuries	.68 ± .06	1.84	.06
Wash.	F	H,F	25	Multiple injuries	.28 ± .03	0.74	.11
SOUTHWEST:							
Tex.	F	V	19	Hyperemesis gravidarum	.76 ± .09	2.03	.12

[a] Type of bone: R, rib; V, vertebrae; S, sternum; F, femur; SK, skull; H, humerus.
[b] Age given as of last birthday prior to death.
[c] Sample obtained from surgical procedure.

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their bone strontium–90 content to be low and age-independent (*1*).

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

Most speciments received to date have been vertebrae and ribs. Efforts to collect long bones for comparison of results with British data have not been successful.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the National Center for Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium–90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxylate. The strontium–90 content is then calculated (*3*) from the yttrium–90 radioactivity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium–90) are analyzed periodically and cross-check analyses are carried out quarterly with the Health and Safety Laboratory of the AEC, which performs similar analyses.

The analytical results for strontium–90 in individual bones from persons dying during the fourth quarter (October–December) of 1966 along with other pertinent data (place of residence, sex, bone type, and cause of death), are presented in table 1 in order of increasing age within each geographical sampling region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium–90 per gram of ash (the primary determination), per gram of calcium (for comparison with other data and for purposes of model development), and per gram of bone (as a rough indication of dose). Two-sigma counting errors are reported for the ash concentration. Additional data for the first half of 1966 (January–June) not reported in earlier tabulations, is given in table 2.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–5*).

Recent coverage in ***Radiological Health Data and Reports:***

Period	Issue
January–March 1966	February 1967
April–June 1966	March 1967
July–September 1966	July 1967

Table 2. Supplemental data, strontium-90 in human bone, first half 1966 [a]

Sampling region and State of residence	Sex	Bone type	Age at death (years)	Cause of death	Strontium-90, pCi/g of: Ash ±2σ error	Calcium	Bone
NORTHEAST:							
1st quarter:							
N. Y.	F	V	2	Asphyxiation	1.39 ±0.17	3.80	0.13
Mass	M	V	7	Cystic fibrosis	1.40 ± .13	3.95	.14
N. Y.	M	V	12	Head injury	1.39 ± .17	3.50	.09
Mass	M	V	23	Mental deficiency	.63 ± .07	1.67	.08
CENTRAL:							
1st quarter:							
Wis	M	V	1	Interstitial pneumonia	1.70 ± .15	4.86	0.14
2nd quarter:							
Minn	F	V	6	Familial nephrosis	1.47 ± .21	4.60	0.14

[a] Repeated and more accurate determination of earlier reported value.

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REFERENCES

(1) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(2) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(3) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures. NERHL 64-1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(4) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(5) HALLISEY, R. M., and M. A. WALL. Strontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–4 (August 1967).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Argonne National Laboratory, National Reactor Testing Station, Portsmouth Area Gaseous Diffusion Plant, and the Savannah River Plant.

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[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual. The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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1. Argonne National Laboratory
July–December and Annual Summary 1966[2]

University of Chicago
Lemont, Illinois

The radioactivity of the environment is determined on a continuing basis by measuring the radioactivity in naturally-occuring materials collected both on and off the Argonne National Laboratory site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these materials. The sampling locations discussed in this report are shown in figures 1 and 2.

Air monitoring

Air-filter samples were collected continuously at seven locations on the Argonne site and at five locations off the site. The alpha and beta radioactivities in air filter samples are summarized in table 1. The alpha-particle concentrations were due principally to naturally-occurring radionuclides, and were normal both on and off the site and in the range found in previous years. The beta-particle concentration was due primarily to fission products from nuclear detonations. The increased beta radioactivities in the second and fourth quarters of 1966 were produced by the shorter-lived fission products which originated in the Chinese nuclear tests of May 9 and October 27, 1966. The average beta radioactivity for the year, 0.16 pCi/m^3, was about 0.1 pCi/m^3 less than

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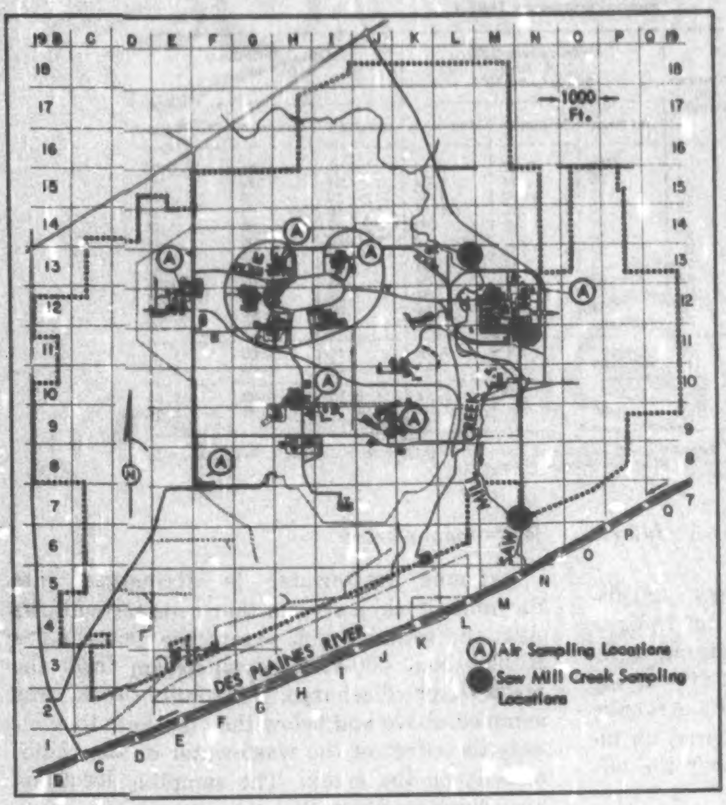
[2] Summarized from "Environmental Radioactivity at Argonne National Laboratory, July–December and Annual Summary 1966," University of Chicago, Lemont, Ill.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DES PLAINES RIVER
SAW MILL CREEK
Air Sampling Locations
Saw Mill Creek Sampling Locations

Figure 1. Sampling locations on the site of Argonne National Laboratory

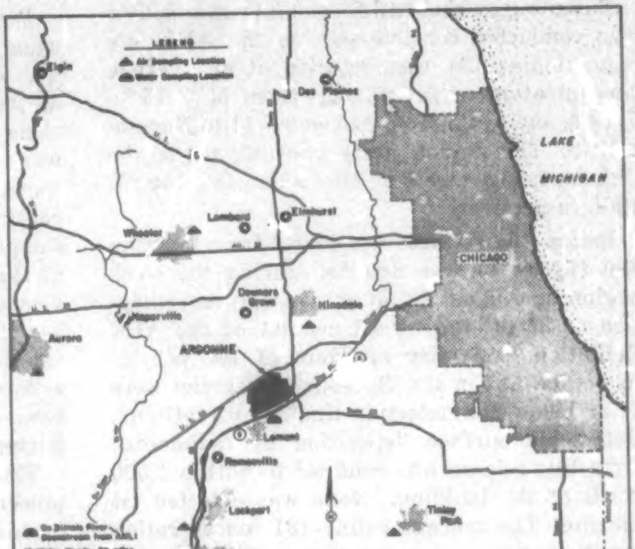
LEGEND
Air Sampling Location
Water Sampling Location
Elgin
Des Plaines
LAKE MICHIGAN
Lombard
Elmhurst
Wheaton
CHICAGO
Downers Grove
Hinsdale
Naperville
Aurora
ARGONNE
Lemont
Romeoville
Lockport
Tinley Park
Joliet
On Illinois River Downstream from ANL
McKinley Woods - 20 miles
Morris - 30 miles
Starved Rock - 60 miles
Scale in Miles

Figure 2. Site location of Argonne National Laboratory (including some offsite sampling stations)

Table 1. Alpha and beta radioactivity in air-filter samples, Argonne, July–December and annual summary 1966 [a]

Period	Location	Number of samples	Alpha radioactivity (pCi/m³) multiply by 10^{-3}			Beta radioactivity (pCi/m³)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
July	onsite	24	0.59	0.37	1.19	0.20	0.00	0.30
	offsite	22	.52	.24	1.03	.21	.12	.33
August	onsite	26	.53	.22	0.87	.10	.05	.15
	offsite	23	.60	.15	1.12	.10	.03	.16
September	onsite	25	.57	.25	.88	.07	.04	.10
	offsite	22	.50	.31	.77	.08	.05	.10
October	onsite	23	.55	.35	.75	.06	.04	.07
	offsite	19	.55	.31	.85	.06	.03	.07
November	onsite	24	.53	.22	1.04	.53	.05	1.94
	offsite	23	.55	.30	.98	.55	.04	2.54
December	onsite	23	.37	.21	.64	.08	.03	.30
	offsite	21	.46	.16	1.31	.09	.04	.23
July-December	onsite	140	.53	.21	1.19	.19	.03	1.94
	offsite	130	.53	.15	1.31	.18	.03	2.54
Annual summary	onsite	288	0.47	0.10	1.19	0.15	0.03	1.94
	offsite	253	0.47	0.14	1.31	0.16	0.03	2.54

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

during 1965 due to a general decline in fallout 1966, respectively.

The similarity between alpha, beta, and fission product radioactivities on and off the site indicates that Argonne did not add significantly to the particulate airborne radioactivity of the environment. Significant releases by Argonne would have been detected in the form of an increase in the onsite radioactivity over the offsite radioactivity.

Sampling on charcoal for gaseous radioiodine was conducted continuously on the ANL site only. Iodine–131 was detected at an average concentration of 0.1 pCi/m³ from May 15 to June 9, and again from November 11 to November 18. This radioactivity is attributed to the Chinese nuclear tests of May 9 and October 27, 1966 respectively.

Iodine–131 released accidently from building 330 (figure 1) was detected during the week beginning August 28, at an average concentration of 38 pCi/m³, or 38 percent of the AEC Radiation Protection standard of 100 pCi/m³ for iodine–131 in air. Subsequent samples were at or below the detection limit of 0.1 pCi/m³. Detectable surface deposition of radioiodine from this release was confined to within 1,000 yards of the building. None was detected off the site. The average iodine–131 concentration for the entire year was less than the detection limit of 0.1 pCi/m³.

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a stream that runs through the Argonne grounds and enters the Des Plaines River about 500-yards downstream from the wastewater discharge. Sawmill Creek was sampled above and below the discharge to evaluate the effect of the wastewater on the radioactivity in the creek. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was usually sampled three times weekly. Since it was impractical to analyze all the samples for all the nuclides and elements desired, equal portions of the three samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Additional samples were collected when unusual amounts of radioactivity were expected or found in the wastewater. Above the site, samples were collected at weekly intervals, and at least one sample each month was analyzed for each radioactive nuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during 1966 are given in table 2.

The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of uranium, thorium, and plutonium. The alpha radioactivities due to these elements are summarized in table 3. As indicated in the table,

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Table 2. Non-volatile alpha and beta radioactivity in Sawmill Creek water, Argonne July–December and annual summary 1966

Month	Location [a]	Number of samples	Alpha radioactivity (pCi/liter) Average	Alpha radioactivity (pCi/liter) Minimum	Alpha radioactivity (pCi/liter) Maximum	Beta radioactivity (pCi/liter) Average	Beta radioactivity (pCi/liter) Minimum	Beta radioactivity (pCi/liter) Maximum
July	Upstream	3	1.9	0.5	4.0	16	10	23
	Downstream	18	2.5	1.2	4.3	440	18	9,600
August	Upstream	5	1.8	.9	3.0	10	6.7	13
	Downstream	12	1.9	1.1	2.2	17	12	25
September	Upstream	3	2.0	.9	3.5	9.7	7	12
	Downstream	15	1.3	.2	2.1	15	12	23
October	Upstream	3	28	1.5	42	13	12	13
	Downstream	12	1.3	.4	1.4	12	9.4	15
November	Upstream	3	1.5	1.2	1.7	13	13	14
	Downstream	12	1.3	.8	1.8	15	12	23
December	Upstream	2	2.5	2.1	2.9	8.6	5.8	11
	Downstream	15	2.1	1.8	2.7	12	9.1	17
July-December	Upstream	17	2.1	.5	4.2	12	5.5	23
	Downstream	81	1.8	.2	4.3	85	9.1	9,600
Annual summary	Upstream	42	2.1	0.1	4.2	11	5.8	23
	Downstream	159	2.6	0.2	12.7	54	9.1	9,600

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

the average as well as maximum amounts of these elements present in the creek as a result of their presence in Argonne waste-water were very low compared to the AEC standards. The average uranium and thorium concentrations below the outfall during 1966 were about one-half of those during 1965, while the plutonium concentration averaged about five times greater.

Table 3. Alpha-emitting elements in Sawmill Creek water Argonne, July–December 1966

Element	Location [a]	Number of samples	Concentration (pCi/liter) Average	Concentration (pCi/liter) Minimum	Concentration (pCi/liter) Maximum	Average as a percent of AEC Standard
Uranium	Upstream	12	1.1	0.4	1.6	0.003
	Downstream	78	1.0	0.5	1.8	0.003
Plutonium	Upstream	6	------	------	<0.05	
	Downstream	48	<0.05	<0.05	0.21	<0.001
Thorium	Upstream	6	<0.05	<0.05	0.06	<0.003
	Downstream	48	<0.05	<0.05	0.14	<0.003

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

In addition to the natural beta radioactivity in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations, and beta radioactivity from Argonne waste-water was found below the outfall. The natural beta radioactivity is approximately 5 pCi/liter above the site and 3 pCi/liter below the site. It is estimated that fallout radioactivity added an average of about 5 pCi/liter to the beta radioactivity at both locations (fallout is added to the water below the outfall directly from the air as well as by above-site water), and that the Argonne contribution below the outfall averaged approximately 45 pCi/liter, about nine times more than during 1965. A release of promethium–147 resulted in the maximum concentration (9,600 pCi/liter) of beta radioactivity for July. This level amounts to 4.8 percent of the annual average AEC radiation protection standard for this radionuclide.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne waste water to the environmental radioactivity. The Des Plaines River was sampled weekly, when water was available, above and below the mouth of Sawmill Creek to detemine if the radioactivity in the creek had any effect on the radioactivity in the river. The average total radioactivity in these two rivers are summarized in table 4 for the second half of 1966.

Table 4. Average radioactivity in Des Plaines and Illionis River water, Argonne, 1966

Location	Concentration (pCi/liter) Non-volatile alpha radioactivity	Concentration (pCi/liter) Non-volatile beta radioactivity
Des Plaines River [a] (above Sawmill Creek)	2.7	19
Des Plaines River [b] (below Sawmill Creek)	2.6	16
Illinois River [c]	4.1	12

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.
[b] Sampled near Lemont, downstream from the mouth of Sawmill Creek.
[c] Average for samples collected at three locations (McKinley Woods State Park, Morris, and Starved Rock State Park) on May 12, 1966.

Dilution of Sawmill Creek water in the Des Plaines River was sufficient to reduce the radioactivity in the creek to undetectable levels in the river. The alpha radioactivity in the Des Plaines River was normal and in the range previously found. The natural beta radioactivity in the Des Plaines River is about 5–10 pCi/liter and the additional radioactivity, about 10 pCi/liter on the average, resulted from fallout. The total radioactivity in samples of the Illinois River water collected on May 12 was similar to that found in other bodies of water in the area and no radioactivity originating at Argonne could be detected.

Milk monitoring

Three samples of raw milk produced in the area were collected monthly (except in May, when an additional collection was made after the appearance of fresh fallout and in December, when one sample was obtained) and analyzed for the fission products usually present. These fission products were all due to fallout from nuclear detonations and their presence in milk was not related to Argonne operations. The long-lived fission products, cesium–137 and strontium–90 were present in all samples. Their average concentrations, 46 pCi/liter for cesium–137 and 8.2 pCi/liter for strontium–90 were not greatly different from those found in 1965.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	September 1966
January–June 1966	March 1967

2. National Reactor Testing Station July–December and Calendar Year 1966[3]

Health and Safety Division
U.S. Atomic Energy Commission
Idaho Falls, Idaho

Data from the environmental monitoring network on and around the National Reactor Testing Station (NRTS) in eastern Idaho revealed that NRTS operations during 1966 did not contribute significantly to environmental radiation or radioactivity concentration levels, which remained well below levels defined as thresholds of concern by the Federal Radiation Council (FRC). The radiation protection standards used at the NRTS, which are established in AEC Manual Chapter 0524, are based on FRC recommendations. In choosing applicable standards for drinking water, credit has been taken for the fact that no significant quantities of radium–226 or radium–228 have been released to the environs by NRTS operations. The concentrations of radioactivity reported include contributions from all sources. No attempt has been made to separate activity contributed by NRTS operations from that contributed by natural sources of radioactivity or by fallout from weapons debris. Samples of air, water, and milk are collected routinely at stations shown in figure 3. The results of the analyses performed on these samples are shown in table 5.

Aerial survey

Results obtained from a detailed aerial survey performed over the NRTS in early 1966 confirmed similar measurements obtained in 1959, and again showed no significant change in environmental radiation background that could be attributed to NRTS operations. Radiation measurements were made along parallel courses 1 mile apart at 500-feet altitude. The survey was performed by an AEC contractor who operates a specially equipped aircraft capable of detecting trace quantities of radioactivity and identifying the material detected. Small variations in the natural background were again noted over varying terrain and were clearly identified with naturally occurring radioactivity in rock and soil formations.

Offsite water monitoring

Low-level liquid wastes from various operating facilities at the NRTS are released to the ground-water table through disposal wells and ponds located near each facility. Before disposal the liquid wastes are carefully monitored at the NRTS and, as an added safeguard, offsite underground water samples are collected and

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[3] Summarized from "Environmental Monitoring Report No. 19, Third and Fourth Quarter and Annual Summary 1966." U.S. Atomic Energy Commission, Idaho Operations Office, Health and Safety Division, National Reactor Testing Station.

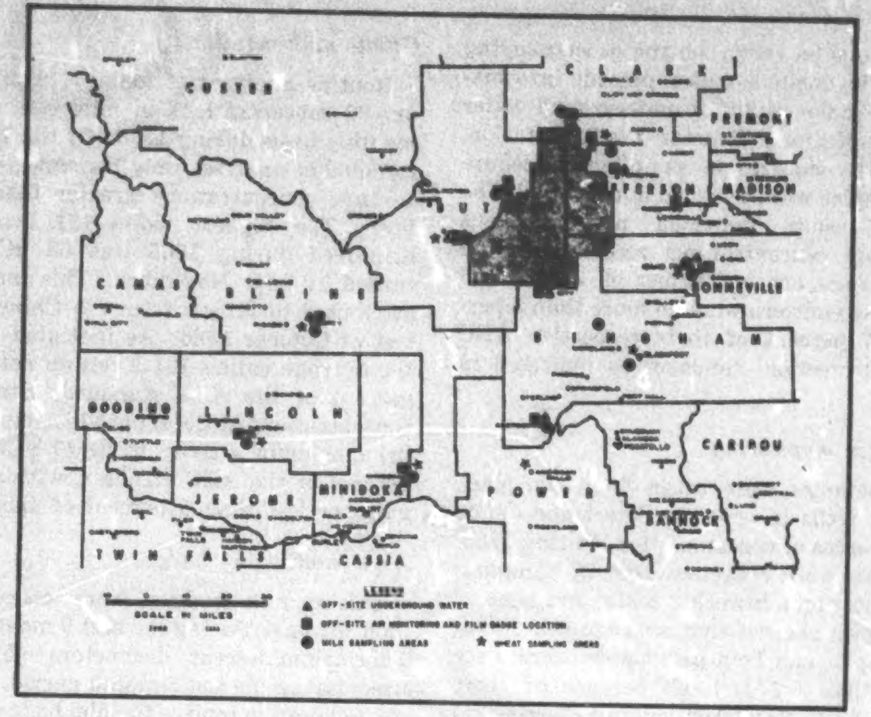
CUSTER
CLARK
FREMONT
BUTTE
JEFFERSON
MADISON
CAMAS
BLAINE
BONNEVILLE
BINGHAM
GOODING
LINCOLN
CARIBOU
MINIDOKA
JEROME
POWER
BANNOCK
TWIN FALLS
CASSIA
LEGEND
SCALE IN MILES
OFF-SITE UNDERGROUND WATER
OFF-SITE AIR MONITORING AND FILM BADGE LOCATION
MILK SAMPLING AREAS
WHEAT SAMPLING AREAS

Figure 3. Environmental monitoring stations, National Reactor Testing Station

analyzed regularly. Most of these samples are taken from an area southwest of the prevalent direction of underground water flow. Since the beginning of the offsite sample collections in 1952, there has been no evidence of any NRTS contribution to the natural radioactivity in the offsite water.

Through continuing studies of the underground water on the NRTS additional knowledge of the directional flow and flow rates have been obtained. As a result of this knowledge the number and locations of sampling points have been reduced to those populated areas nearest the site boundaries. Samples from

Table 5. Environmental monitoring data for the National Reactor Testing Station, July–December and calendar year 1966

Type of sample and units	Number of stations	July–December 1966					Calendar year 1966			
		Approximate frequency of collection	Type of analysis	Minimum level of detection	Maximum radioactivity of single sample	Average radioactivity per sample	Minimum level of detection	Maximum radioactivity of single sample	Average radioactivity per sample	AEC radiation protection standard
Offsite underground water, (pCi/liter)	12	Semiannual	Alpha	3	< 3	< 3	3	< 3	< 3	100
			Beta	6	7	< 7	6	7	< 7	100
Onsite production well water, (pCi/liter)	22	Biweekly	Alpha	3	6	< 4	3	6	< 4	3,000
			Beta	6	17	< 7	6	125	< 8	3,000
Offsite air, (pCi/m³)	12	Continuous	Beta-gamma	1.6	54	< 6	1.6	54	< 8	100
			Iodine-131	3.6	25	< 5	3.6	60	< 5	100
Offsite milk, (pCi/liter)	12	Monthly	Iodine-131	20	63	<22	20	63	<21	100
			Strontium-90	1.5	13	< 7	1.5	17	< 9	200
Offsite area monitoring badges, (mR)	12	Monthly	Gamma	10	<10	<10	10	<10	<10	170/yr

these locations as shown on the accompanying map, plus the onsite samples, provide information on the radioactivity of underground water leaving the National Reactor Testing Station.

Due to the changes in sampling procedure only 12 samples were collected during 1966. The analytical results indicated no significant change from concentrations recorded during 1965. Average concentrations of alpha- and beta-particle emitters were no more than 3 percent and 7 percent of their respective AEC radiation protection standards as indicated in table 5.

Onsite water monitoring

Onsite samples were taken from the plant production wells in order to detect and define possible sources of contamination. During 1966, 430 samples were collected from 22 sampling stations, most on a biweekly basis. Analyses of these samples showed that average concentrations of alpha and beta-particle emitters were no more than 0.2 and 0.3 percent of their respective AEC standards, again reflecting no change from the previous year.

Air monitoring

During 1966, 153 air samples were collected and evaluated for airborne alpha-particle emitters. A gross alpha particle determination was made on filter-paper samples after a sufficient time had elapsed to permit the decay of the short-lived daughter products of radon and thoron. The filter-paper samples were counted for alpha-particle emission by scintillation counters. The average measured concentrations of alpha radioactivity in air was .002 pCi/m^3 or 5 percent of the AEC standard. The radiation protection standard used is that for uncontrolled areas and for gross alpha radio activity for which no analyses for specific isotopes have been made. The alpha radioactivity is attributed primarily to long-lived radioactive elements naturally present in the environment.

Results of the data reported from the 12 offsite radiation telemetry stations indicate that the average concentrations of gaseous iodine-131 and particulate radioactivity in the atmosphere was less than 8 percent of the AEC radiation protection standards.

Offsite milk monitoring

Routine analyses of iodine-131 and strontium-90 concentrations in milk continued on a monthly basis during 1966. Of the 139 routine radioiodine analyses, only 7 samples were found to have concentrations greater than 20 pCi/liter. The highest iodine-131 concentration measured during 1966 was 63 pCi/liter recorded in early November. This increase was attributed to fallout from the Chinese nuclear test of October 1966. As indicated in table 5, the average iodine-131 levels do not exceed 21 percent of the AEC standard. Strontium-90 concentrations in the same 139 samples showed the maximum activity to be 17 pCi/liter of 9 percent of the AEC standard with an average value of less than 5 percent of this standard.

Area monitoring badges

Offsite film badges were collected on a monthly basis during the first 9 months of 1966. Thermoluminescent dosimeters (TLD) were used during the last 3-month period. The TLD were chosen to replace the film badges presently used in the NRTS environmental monitoring program. Current plans call for reading the dosimeters on a semiannual basis except in the case of an accident or known exposure.

The radiation exposure at a single location for any month as measured by film badges or TLD's was <10 mR of gamma radiation. The minimum detection limit for the calendar year was 120 mR of gamma radiation, based on 12 changes and a detection limit of 10 mR gamma radiation on each film or TLD. For the purpose of calculating the maximum dose, each statistically zero result was assumed to be at the detection limit. The reported maximum is therefore conservatively estimated to be the upper limit of the true dose at that location. Natural background radiation levels at film badge locations vary, but studies made prior to nuclear operations at the NRTS showed that normal background levels were of the order of 100–150 mR/yr. This indicates that NRTS operations have added no significant external radiation to the surrounding areas.

Wheat monitoring

Monitoring of wheat in southern Idaho continued in 1966. Analysis of 8 samples showed strontium-90 levels ranging from 6 to 14 pCi/kg with an average of 10 pCi/kg. Cesium-137 and manganese-54 activity in the same samples were at or below the detection limit of 35 pCi/kg for cesium-137 and 100 pCi/kg for manganese-54. A comparison of data from the previous year shows that the levels of strontium-90 has decreased by a factor of 2. Cesium-137 and manganese-54 activities are no longer detectable by routine analyses.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December and calendar year 1965	July 1966
January–June 1966	January 1967

3. Portsmouth Area Gaseous Diffusion Plant July–December 1966[4]

Goodyear Atomic Corporation
Piketon, Ohio

The separation of uranium isotopes by the gaseous diffusion process presents control problems similar to any chemical process using toxic solvents and extraction solutions. Natural uranium and thorium-234 are the most likely radionuclides to be released to the environment by the Portsmouth Area Gaseous Diffusion Plant. Since natural uranium is an alpha emitter and thorium-234 is a beta-gamma emitter, environmental monitoring is conducted for evidence of alpha and beta-gamma emitters to test the effectiveness of plant controls.

Air samples are generally collected monthly at 21 sites located from 1 to 6 miles from the plant as shown in figure 4. Monthly water samples are collected at 13 stations within 5 miles of the plant.

Average airborne alpha radioactivity showed a reduction during the second half of 1966 when compared with the first half of 1966. The alpha radioactivity dropped from 7.3 to <5.0 percent of the AEC radiation protection standard. The airborne beta-gamma activity remained essentially the same as the previous 6-month average.

During this period, both the average alpha and beta-gamma radioactivities in water samples showed little change from those for the previous period. The average radioactivity monitored in water amounted to 0.09 percent of the AEC standards for alpha particle and 0.03 percent for beta particle + gamma-ray emitters.

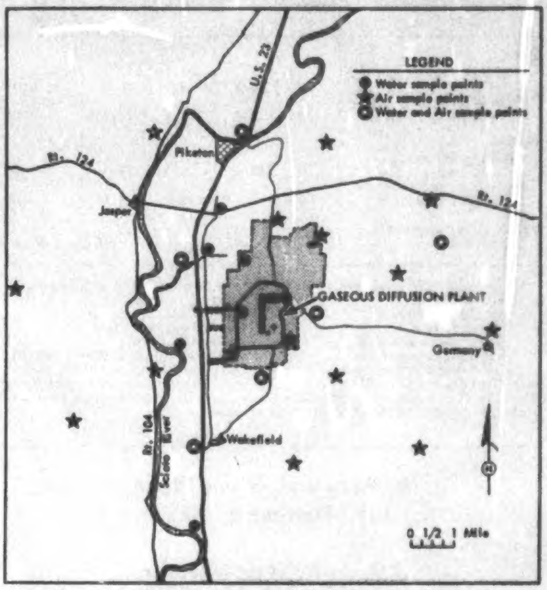

Figure 4. Sampling locations, Portsmouth Area Gaseous Diffusion Plant

Average background exposure rates declined to 17.4 percent of the AEC standard (0.5 rem/yr) during 1966. In the calculations it is assumed that all of the exposure rates are attributable to plant operations. As in the past the offsite and onsite patterns are very much alike in form and intensity with no significant differences between the average values. From the onsite and offsite intensities and the continuing decline in exposure rates which followed the moratorium in nuclear testing activities, it is evident that the plant operations have not added appreciably to the general background radiation.

Average alpha and beta-gamma radioactivity levels in air and water are summarized in table 6. The external gamma-ray levels measured at the air sampling locations shown in figure 4, are also summarized in table 6. The overall average concentrations and background exposure rates for 1966 and the overall 1965 averages are presented in table 7.

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[4] Data summarized from B. Kalman and S. H. Hulett, "Environmental Radiation Levels and Concentrations, Second Half and Annual Summary 1966," GAT-529 (February 13, 1967).

Table 6. Environmental radioactivity, Portsmouth Plant July–December 1966

Type of monitoring	Number of samples	Maximum	Minimum	Average	Average as a percent of AEC standard [a]
Air					
Alpha radioactivity (pCi/m³)	135	0.3	< 0.1	<0.1	< 5.0
Beta-gamma radioactivity (pCi/m³)	135	2.4	< .1	< .1	0.01
Water					
Alpha radioactivity (pCi/liter)	71	384	< .5	18.1	.09
Beta-gamma radioactivity (pCi/liter)	71	355	<14.0	6.9	.05
Background exposure [b] (mrad/hr)	126	.034	.011	.018	17.1

[a] The applicable AEC radiation protection standards are as follows:

Air (alpha)	2 pCi/m³
Air (beta-gamma)	1×10³ pCi/m³
Water (alpha)	2×10⁴ pCi/liter
Water (beta-gamma)	3×10⁴ pCi/liter
External beta-gamma	0.5 rem/yr (approx. 0.06 mrad/hr)

[b] Measurements were made with an open-shield Geiger-Mueller tube 1 foot above ground. The 3-foot rate (not shown) was experimentally determined to average two-thirds of the 1-foot rate and was used to determine the percent of the concentration standard.

Table 7. Comparison of average concentrations, Portsmouth Plant, 1965 and 1966

Type of monitoring	Percent of AEC radiation protection standard [a]			
	1966			1965
	First half	Second half	Calendar year	Calendar year
Air				
Alpha radioactivity	7.3	< 5.0	1.4	12.6
Beta-gamma radioactivity	0.03	0.01	0.02	0.03
Water				
Alpha radioactivity	.07	.09	.09	.30
Beta-gamma radioactivity	.07	.05	.05	.32
Background exposure extrapolated to 3 feet above ground level	17.7	17.1	17.4	27.7

[a] See footnote (a) of table 6.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1965	July 1966
January–June 1966	January 1967

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4. Savannah River Plant
July–December 1965[5]

E. I. du Pont de Nemours
Aiken, South Carolina

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, four reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low-level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

The DuPont environmental monitoring group has maintained a continuous monitoring program since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200-square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the maximum permissible concentrations (MPC) recommended by the International Commission on Radiological Protection (ICRP), or the daily intake guides recommended by the Federal Radiation Council (FRC).

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity cannot be readily distinguished from weapons tests fallout, and both are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

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[5] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, July–December 1966" (DPST–67–30–1).

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by weekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about 25-mile radius from the center of the plant (figure 5). Deposition rates of radioactive material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S.C., are so distant from SRP that the effect of SRP operations is negligible; they are reference points for determining background radioactivity levels (figure 6). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between weapons test fallout and SRP releases.

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separations areas, was obscured by fallout from nuclear weapons tests. The influence of the weapons tests which resumed in September 1961 is shown in figure 7. The rises in early 1964, 1965, and 1966, were the result of the anticipated spring increases in

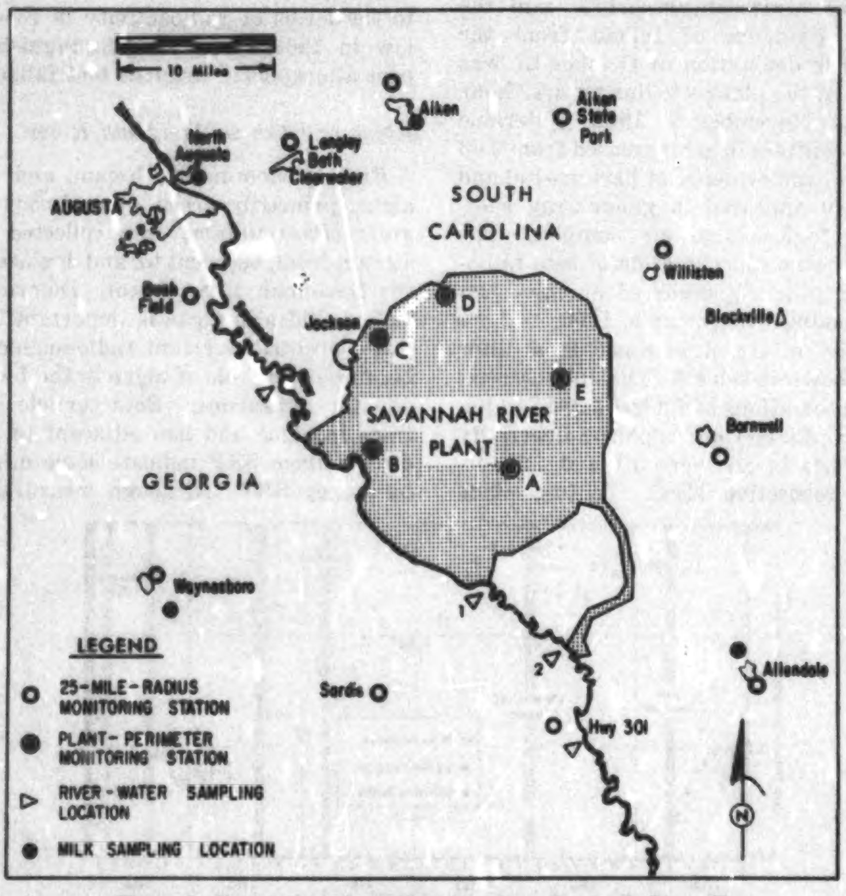
10 Miles
Aiken
Aiken State Park
North Augusta
Langley Bath Clearwater
AUGUSTA
SOUTH CAROLINA
Williston
Bush Field
Jackson
Blackville
D
C
E
SAVANNAH RIVER PLANT
B
A
Barnwell
GEORGIA
Waynesboro
1
2
LEGEND
Allendale
25-MILE-RADIUS MONITORING STATION
Sardis
PLANT-PERIMETER MONITORING STATION
Hwy 301
RIVER-WATER SAMPLING LOCATION
MILK SAMPLING LOCATION
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Figure 5. Environmental sampling locations, Savannah River Plant

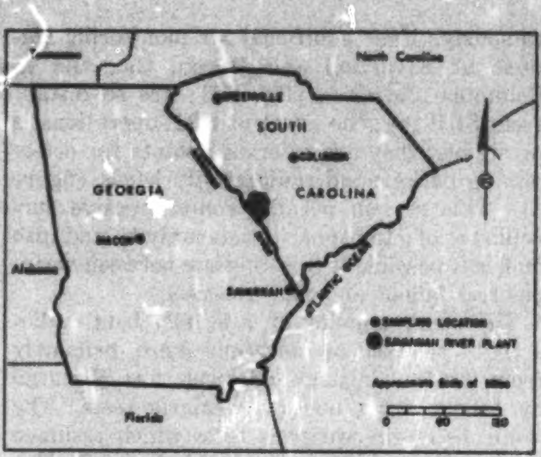

Figure 6. Distant air monitoring station Savannah River Plant

the mixing of stratospheric debris into the troposphere. Evidence of fallout from the Chinese nuclear detonation of October 27 was first detected at the plant site during a 72-hour period ending November 7, 1966. Filterable beta-particle emitters in air increased from 0.03 to 0.78 pCi/m^3, and evidence of barium–140 and lanthanum–140 appeared in gamma-ray spectrograms of high-volume air samples. The maximum airborne concentration of beta radioactivity (1.23 pCi/m^3), occurred during a 24-hour period ending November 8, 1966.

Radioactivity in air, determined from filter analyses, is shown in table 8. The July–December 1966 concentrations of filterable beta radioactivity (0.09 pCi/m^3) and alpha radioactivity (0.0007 pCi/m^3) in air were 0.1 and 1.8 percent of the respective MPC. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile stations, did not exceed 1.1 percent of the MPC. Iodine–131 concentrations in routine air samples were less than 0.02 pCi/m^3, the lower detection limit, throughout the period.

Deposition of weapons tests fallout during the last half of 1966 totaled 27 nCi/m^2 at plant perimeter locations and 21 nCi/m^2 at 25-mile radius locations; comparable values for the first half of 1966 were 96 and 70 nCi/m^2. Fallout from the Chinese weapons test (primarily short-lived barium-lanthanum–140) accounted for the large increase. Beryllium–7, an isotope continuously being produced in nature by cosmic interactions in the upper atmosphere, was a measurable component in environmental radioactivity. Deposition at each sampling location is presented in table 9 SRP contributions to the levels of radioactivity in foods were so low in 1966 as to be indistinguishable from past atmospheric weapons test fallout.

Algae and fish in Savannah River

Fish, predominantly bream, and indigenous algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected weekly upstream from, adjacent to, and downstream from the Savannah River Plant. Determination of radionuclides in algae is important because algae concentrate certain radionuclides and also because of the role of algae in the food chain of aquatic organisms. Beta-particle concentrations in algae and fish adjacent to and downstream from SRP indicate some minor contribution by SRP. Although measurably higher

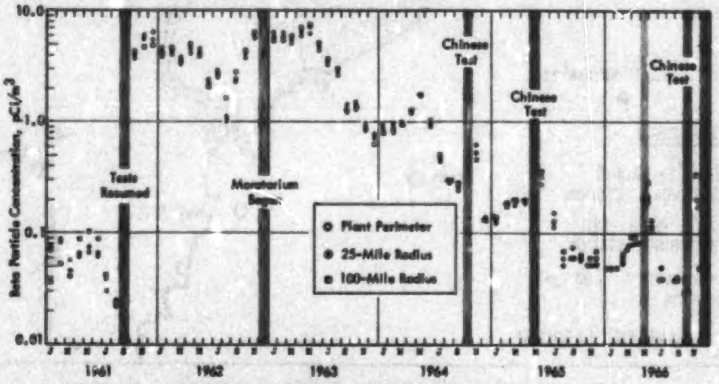

Figure 7. Influence of weapons tests

Table 8. Radioactivity in air, Savannah River Plant, July-December 1966

Filter analysis	Average concentration (pCi/m³)																
	Plant perimeter locations						25-mile radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha particle emitters[a] (multiply by 10^{-3})																	
Maximum	1.3	1.8	1.1	1.4	1.0	------	1.0	1.0	1.1	1.2	1.1	1.2	0.8	1.1	2.1	0.9	
Minimum	0.3	0.4	0.4	0.3	< .2	------	0.4	0.3	< 0.2	0.4	0.4	0.4	< .2	0.3	< 0.2	.2	
Average	.7	.7	.7	.7	.6	0.7	.6	.6	.6	.7	.6	.7	.5	.6	.9	.6	0.6
Nonvolatile beta-particle emitters[b]																	
Maximum	.28	.20	.22	.31	.22	------	.23	.22	.22	.21	.15	.21	.41	.34	.27	.16	
Minimum	.03	.02	.03	.03	.02	------	.03	.03	.02	.03	.02	.03	.02	.02	.03	.02	
Average	.10	.08	.09	.10	.08	.09	.08	.08	.08	.09	.08	.07	.09	.09	.10	.07	.08
Specific radionuclides (averages)			Composite sample									Composite sample					
Strontium-89,-90			0.005									0.008					
Cesium-137			.005									.004					
Cerium-141,-144			.053									.027					
Ruthenium-103,-106			.090									.037					
Zirconium-niobium-95			.008									.006					
Manganese-54			< .002									< .003					

[a] Sensitivity of analysis—3.0×10⁻⁴ pCi/m³; ICRP Maximum Permissible Concentration: 0.04 pCi/m³.
[b] Sensitivity of analysis—0.005 pCi/m³; ICRP Maximum Permissible Concentration: 100 pCi/m³.

Table 9. · Total fallout deposited, Savannah River Plant, July-December 1966

Radionuclide	Deposition (nCi/m²)																
	Plant perimeter locations						25-mile radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha[a]	2.82	2.43	5.02	2.56	2.93	3.17	1.70	3.13	3.22	2.01	3.17	6.02	2.90	4.86	2.55	2.55	3.20
Strontium-89	2.20	1.00	1.96	1.62	1.85	1.74	1.56	1.58	2.01	2.39	1.39	1.31	2.26	1.04	1.81	1.70	1.70
Strontium-90	0.54	0.52	0.88	0.54	0.56	0.62	0.58	0.62	0.46	0.56	0.77	0.58	0.69	0.85	0.54	0.54	0.62
Iodine-131	------	------	------	------	.42	.08	------	------	.30	------	------	------	------	------	.46	------	.08
Cesium-137	1.39	.96	1.20	.96	1.20	1.16	.73	.66	.62	.42	.54	.58	.50	.66	.62	.46	.58
Cerium-141, -144	2.86	1.75	4.06	3.05	2.78	2.90	2.34	.93	1.70	1.47	2.66	3.47	2.55	1.54	1.37	5.87	2.28
Ruthenium-103, -106	4.05	[illegible]	3.34	3.01	2.34	3.13	2.97	2.67	1.78	1.78	2.74	3.17	2.55	1.61	1.54	6.33	2.78
Barium-lanthanum-140	5.44	6.50	7.99	5.52	5.71	6.29	6.76	6.18	4.63	3.86	8.07	5.48	5.48	3.98	3.63	3.59	5.17
Zirconium-niobium-95	4.17	1.12	7.68	3.71	3.16	3.98	2.78	.77	1.62	1.54	6.87	4.36	5.86	1.47	1.34	15.63	4.01
Manganese-54	.08	------	.12	[illegible]	------	.04	------	.04	.08	.12	.08	.12	.08	.06	.08	.04	.08
Beryllium-7	6.71	4.75	5.90	7.33	6.57	7.06	4.96	3.86	3.01	3.74	3.55	3.71	3.17	2.55	5.37	5.17	3.90

[a] Multiply by 10^{-3}.

than similar material collected at the control station 3-miles upstream from SRP, the slight increase is of no biological significance.

Specific radionuclide analyses were made on algae and fish collected from the Savannah River. Radiocesium and radiostrontium were found consistently in river algae; whereas cerium-141-144, chromium-51, zirconium-niobium-95, manganese-54, zinc-65, and cobalt-60 were detected less frequently. Also, radiostrontium (maximum, 12 pCi/g, wet weight) was detected in bone tissue of river fish, and radiocesium (maximum 7 pCi/g, wet weight) was detected in the flesh tissue. Radiozinc and phosphorous-32 were detected less frequently in these tissues. The maximum concentrations of phosphorous-32 detected in bone and flesh tissues of river fish were 430 pCi/g and 12 pCi/g, respectively.

Water monitoring

The plant site is drained by five streams which flow several miles through the reservation before reaching the river (figure 8). In

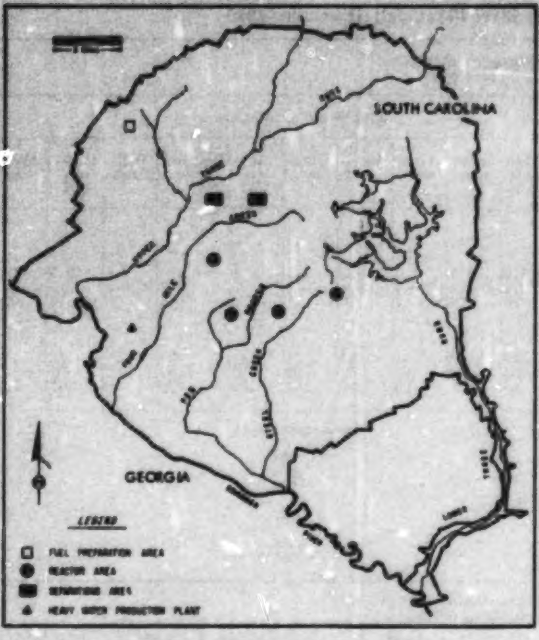

Figure 8. SRP production areas and effluent streams

January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish drinking water, partially supplied from the Savannah River, to most of Beaufort County, South Carolina. Water is supplied through a new canal from the river at a location about 90 miles below the SRP. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand.

Communities near SRP get domestic water from deep wells or surface streams. Public water supplies from 14 surounding towns were collected and analyzed in October. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.2 pCi/liter) and beta radioactivity (5 pCi/liter) were essentially the same as those observed before plant startup.

Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or absorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at nine other locations along a 25-mile radius route (not designated on figure 5). Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis. Radionuclides in grass samples were from weapons test fallout. Alpha-particle emitters averaged 0.1 pCi/g at the plant perimeter and 25-mile radius locations as compared to 0.2 pCi/g during the first half of 1966; gamma-ray emitters averaged 24 and 21 pCi/g, respectively, as compared to 51 and 38 pCi/g for the first half of 1966.

Milk

Milk was sampled at four dairies within a 25-mile radius of SRP, as shown in figure 5. Samples which were collected biweekly, were analyzed for tritium, radiocesium, and radioiodine. Strontium-90 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during July–December 1966 are in table 10.

Average concentrations of three radionuclides in milk (31 pCi/liter for cesium-137, 20 pCi/liter for strontium-90, and less than 5 pCi/liter for iodine-131) were consistent with values reported by the U.S. Public Health Service for most sections of the United States during the second half of 1966. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level was less than the sensitivity of the analysis, which allows detection of concentrations of 3,000 pCi/liter (1 percent of the MPC for water).

Food

Forty-seven samples representing 4 food categories (fruit, grain, leafy vegetable, and poultry) were collected during the summer and fall of 1966 at 14 localities in the 6 counties surrounding SRP (not shown on figure 5). With the exception of grains, all foods were prepared for analysis in a manner similar to that used to prepare them for eating. Peelings, seeds, and other nonedible parts were removed.

Table 10. Radioactivity in milk from local dairies, Savannah River Plant, July–December 1966

Location of local dairies	Concentration (pCi/liter)									
	Tritium [a]			Strontium-90 [b] [c]		Iodine-131 [d]			Cesium-137 [e]		
	Maximum	Minimum	Average	July 1966	December 1966	Maximum	Minimum	Average	Maximum	Minimum	Average
Aiken	5,000	<3,000	<3,000	22	16	<5	<5	<5	50	<30	35
Allendale	<3,000	<3,000	<3,000	10	NS	<5	<5	<5	64	<30	51
North Augusta	5,000	<3,000	<3,000	29	18	<5	<5	<5	49	<30	<30
Waynesboro	4,600	<3,000	<3,000	22	24	<5	<5	<5	42	<30	<30
Major distributions [f]	3,800	<3,000	<3,000	23	18	<5	<5	<5	66	<30	42

[a] Sensitivity of analysis—3,000 pCi/liter.
[b] Sensitivity of analysis—1.0 pCi/liter.
[c] Strontium-90 determinations were made quarterly.
[d] Sensitivity of analysis—5 pCi/liter.
[e] Sensitivity of analysis—30 pCi/liter.
[f] Milk produced in local dairies, but sold by major distributors.
NS, no sample collected.

Wheat, containing the whole grains only, and oats, containing both grains and husks, were processed unwashed. Gamma-ray spectrometry was used to analyze samples for cerium–141–144, ruthenium–103–106, iodine–131, cesium–137, manganese–54, and zirconium-niobium–95. Radiostrontium and alpha radioactivity (uranium and plutonium) were determined by radiochemical analysis.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 5. Average concentrations of specific radionuclides found in river water during July–December 1966 are in table 11.

Table 11. Average concentration of radionuclides in Savannah River water, July–December 1966

Radionuclide	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (3 miles upstream from plant)	Highway 301 (10 miles downstream from plant)	Percent MPC at Highway 301
Tritium	600	1,000	11,000	1.2
Ruthenium-103, -106	3.2	<3.2	< 3.2	<0.10
Cerium-141, -144	2.5	<2.5	< 2.5	< .08
Cesium-134, -137	0.6	<0.6	3.2	.05
Neptunium-239	.9	< .9	4.6	.02
Barium-lanthanum-140	1.6	<1.6	< 1.6	< .02
Zirconium-niobium-95	.5	< .5	.6	.008
Chromium-51	4.3	<4.3	13.4	.003
Strontium-89	.3	< .3	1.0	
Iodine-131	.5	< .5	< .5	
Strontium-90	.01	.9	1.5	
Cobalt-60	1.4	<1.4	< 1.4	< .01
Zinc-65	1.1	<1.1	< 1.1	< .01
Manganese-54	.4	< .4	< .4	< .001

Cesium–137, strontium–89, strontium–90, chromium–51, tritium, and trace amounts of cerium–141, zirconium-niobium–95, and iodine–131, released mainly from reactor areas, were the radionuclides of SRP origin dectectable in river water at the downstream location. Average concentrations of all radionuclides found in river water during July–December 1966 were only small fractions of the permissible concentrations. The tritium concentrations in finished water collected from the Beaufort-Jasper Water Plant averaged 8,300 pCi/liter (0.8 percent of the MPC) during the 6-month report period.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy water moderator in the reactors. Chromium–51, the second most abundant radionuclide released to the river, is produced by neutron irradiation of stable chromium (a component of the stainless steel used in reactor parts). Tritium and chromium–51 are among the least dangerous of all radionuclides because neither concentrates in body tissues. The tritium and chromium–51 concentrations in river water averaged 1.2 and 0.003 percent of the MPC, respectively.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The July–December 1966 data (table 12) are characteristic of measurements observed at individual stations for the past several years.

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Table 12. Environmental gamma radiation, Savannah River Plant, July–December 1966

	Exposure (mR/day)																
	Plant-perimeter locations						25-mile radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bush Field	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Maximum	0.29	0.27	0.32	0.28	0.29	------	0.26	0.20	0.26	0.30	0.31	0.26	0.29	0.27	0.29	0.28	
Minimum	.24	.21	.18	.19	.19	------	.13	.15	.17	.21	.21	.14	.17	.12	.16	.17	
Average	.26	.24	.27	.24	.24	0.25	.21	.17	.22	.26	.24	.21	.24	.22	.24	.23	0.23

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
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SECTION V. TECHNICAL NOTES

Environmental Radioactivity in Woods Soil from Dover, New Jersey During 1964—1966

Samuel Helf[1]

In 1963 an extensive environmental radioactivity measurement program for gamma-emitting radionuclides was initiated on the U.S. Army Picatinny Arsenal military reservation and the surrounding region. These measurements were made primarily to provide a basis for distinguishing between radioactivity resulting from worldwide nuclear fallout and potential contamination from onsite radiological operations. The latter includes the operation of several multi-kilocurie sources of gamma radiation for radiation effects studies and both low- and high-level radiotracer experiments for research and development applications. Initially, samples assayed included grass, leaves, river and lake water, lake and stream mud, and precipitation. Results of these measurements are described in another report (*1*).

In 1964, this sampling program was expanded to include woods soil because it was observed that, on a unit weight basis, the quantity of radioactivity was considerably greater than in other types of environmental samples. This woods soil sampling program was continued on an approximately monthly basis through October of 1966 and these results are described here.

Experimental

Samples were collected from a wooded hillside at the inlet end of Lake Picatinny located approximately in the center of the military reservation. Trees on this site are primarily deciduous, consisting mainly of oak trees common to the general area. Samples were taken from the top 2 inches of soil after the surface litter was brushed away. All stones, twigs, leaves and other extraneous matter were carefully removed and the resulting soil was dried to constant weight at 110° C. The 1964 samples were counted in waxed cardboard containers (Disposo Cups) having a volume of 150 cc, the average weight of soil being approximately 40 grams. In 1965 and 1966 samples were counted as 1.0 liter volumes in a Marinelli-type polyethylene beaker. The average weight of soil here was 288 grams.

Radioassay was performed by gamma-ray spectrometry. Resolution of individual radionuclides was accomplished with the aid of an IBM–7090 electronic computer using either simultaneous equations (*2*) or weighted linear least squares (*3*) techniques. The scintillation detector consisted of a 4- by 4-inch sodium iodide (thallium-activated) crystal coupled to a 3-inch window multiplier phototube. The detector assembly was housed in an Oak Ridge National Laboratory type "pickle-barrel" lead shield consisting of 3 inches of lead all around. The signal from the detector was fed into a 400-channel pulse-height analyzer. Counts were accumulated in 200 channels of the memory with the analyzer calibrated for 10.0 keV per channel. Thus the energy range scanned was from 0 to 2 MeV. Each sample was counted for at least 100 minutes .

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The library of standards used in the computer programs was made from reference solutions of known specific radioactivity. These standards were counted as aqueous solutions under the same geometry conditions as the unknowns.

Results

Five nuclear fallout gamma-emitters were determined in each soil sample. These nuclides and their respective half-lives are manganese-54 (314 days), ruthenium-106 (1.0 years), antimony-125 (2.7 years), cesium-137 (30 years), and cerium-144 (285 days). The origin of these radionuclides is presumed to be from "aged" nuclear fallout resulting from atmospheric tests conducted by the United States and Soviet Russia through the fall of 1962. Zirconium-95 (65 days) was observed in the early 1964 soil collections in concentrations from about 1 to 10 pCi/g but was no longer detectable after June of that year. This nuclide was again observed at barely detectable levels (about 1 pCi/g) in June 1966, and in the subsequent 1966 collections. The reappearance of zirconium-95 is presumed to have originated from recent Chinese nuclear experiments on the Asian mainland.

Naturally-occurring potassium-40 was also measured. No artificial radioactivity whose origin can be attributed to local sources was detectable.

The gamma-ray spectra of three soil samples collected at 1 year intervals from the Picatinny Arsenal location are shown in figure 1. Gross counts normalized to unit time and weight, are plotted logarithmically on the ordinate. The abscissa is given in channels corresponding to 10 keV of gamma-ray energy per channel. Taking into account differences in relative concentrations, the shapes of all three spectra are similar. It is therefore concluded that the composition of the spectra remained constant during the 2-year period, differing only in the concentrations of the individual species.

The concentrations in the woods soil of each of the five long-lived artificial radionuclides, in pCi/g, are shown graphically in figure 2, from February 1964, to October 1966. No significant differences are observed among the concentration profiles of the five elements. Thus, there appears to be no important selective uptake or retention of any one radionuclide over another in this particular type of soil.

The average annual concentration for each

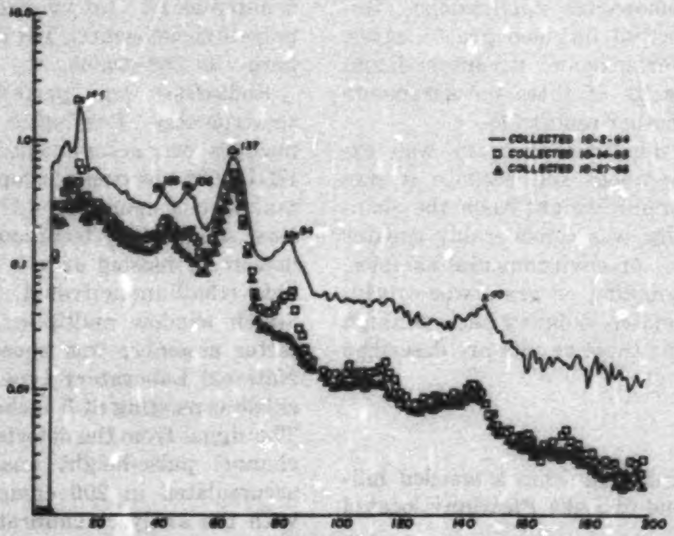

Figure 1. Gamma-ray spectra of three woods soil samples collected from the same Picatinny Arsenal location at 1-year intervals

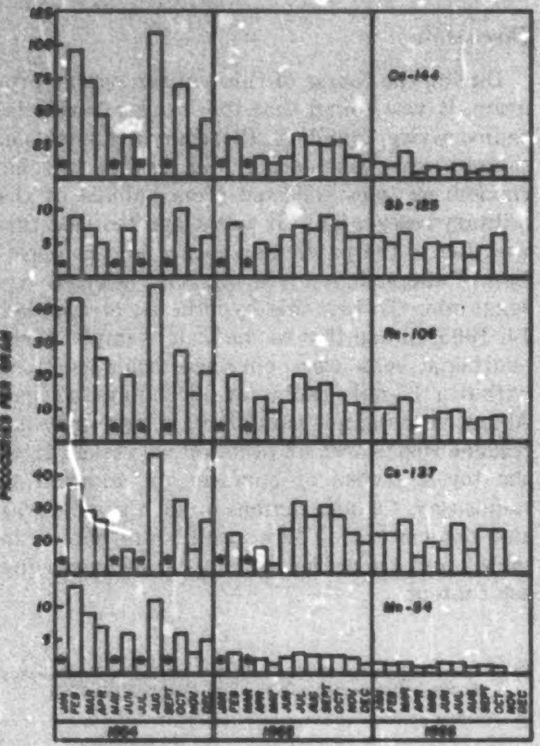

Figure 2. Concentrations of fallout radionuclides in Picatinny Arsenal woods soil, as recorded monthly, 1964–1966
*Indicates that no sample was collected for that month

artificial radionuclide, during this period, is given in table 1. Also included are the average annual measured potassium–40 concentrations.

Total precipitation on a monthly basis during this collection period is shown in figure 3. There is no obvious correlation observed between these precipitation levels and the monthly radionuclide concentrations.

Accuracy of measurements

It is difficult to estimate an absolute accuracy of radionuclide analysis for environmental samples which have been radioassayed by gamma-ray spectrometry. This is primarily because the qualitative radionuclide composition of an environmental sample is assumed. As a result, statistical treatments of data obtained by electronic computer methods give only measures of agreement or "goodness of fit" between the measured spectra and the fixed library of reference standards.

Table 1. Average annual radionuclide concentrations in Picatinny Arsenal woods soil

Radionuclide	Concentration (pCi/g)		
	1964	1965	1966
Cerium-144	60.5	20.7	8.4
Antimony-125	6.0	6.5	5.0
Ruthenium-106	25.4	14.1	8.0
Cesium-137	28.9	23.2	21.0
Manganese-54	7.4	2.8	1.3
Potassium-40	10.9	7.2	7.6

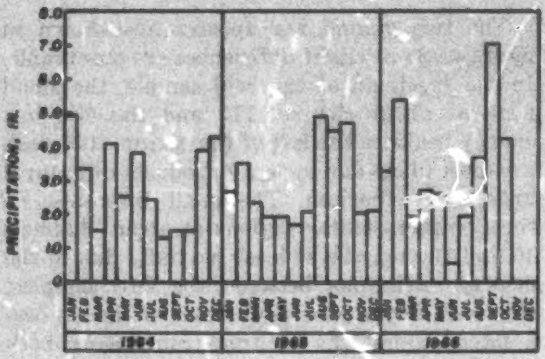

Figure 3. Total precipitation recorded on a monthly basis at Picatinny Arsenal during soil sampling period

Cambray and co-workers (4) have experimentally determined "uncertainty in the analysis" which they designate as σ_a for gamma-ray spectrometric determinations on environmental rainwater and airborne dust samples. Except when near the limits of detection the following nominal values of σ_a are claimed: cerium–144, 8 percent; antimony–125, 20 percent; ruthenium–106, 15 percent; cesium–137, 6 percent; zirconium–95, 6 percent; manganese–54, 7 percent. These reported σ_a values, however, are measures of analytical precision and do not necessarily denote the true error of the determination for a particular radionuclide.

The accuracy of the soil radioactivity measurements described in this report was estimated by comparing the gamma-ray spectrum of a simulated sample of the same composition as determined for a field sample. The simulated sample was made up as 1.0 liter of acidified distilled water and contained the standard reference radionuclides in concentrations to correspond with those determined by computer assay of the November 1965 field sample. Since the actual soil sample weighed 253 g the only known difference between the two samples was that of density, *i.e.*, 0.253 *vs.* 1.0.

The two gamma-ray spectra are shown in figure 4. Some slight differences are observable. In the spectrum of the field sample, the small peak at about channel 170 and the two low energy peaks to the left of the cerium–144 peak are most likely due to decay products of natural uranium or thorium. The small differences in the Compton-scatter regions at about channels 40 and 100 may be at least partially due to the density variations between the two samples. However, in the photopeak areas of the six designated gamma-ray emitters comprising both the soil and simulated samples, the spectra are strikingly similar. The original assumption as to the radionuclide composition of the soil is therefore sound with regard to detectable species and errors in the analysis due to a departure from this assumption are negligible.

The true errors in these measured radionuclide concentrations can therefore be assessed in terms of experimental and analytical factors which are either known or can be reliably estimated. These are the accuracy of the reference calibration standards, computer resolution errors, counting statistics, and sampling errors, in that order of importance. On this basis, the artificial radionuclide concentrations as given in this report, are estimated to be accurate to ± 10 percent for ruthenium–106, ± 6 percent for cesium–137, and ± 15 percent for cerium–144, antimony–125, and manganese–54.

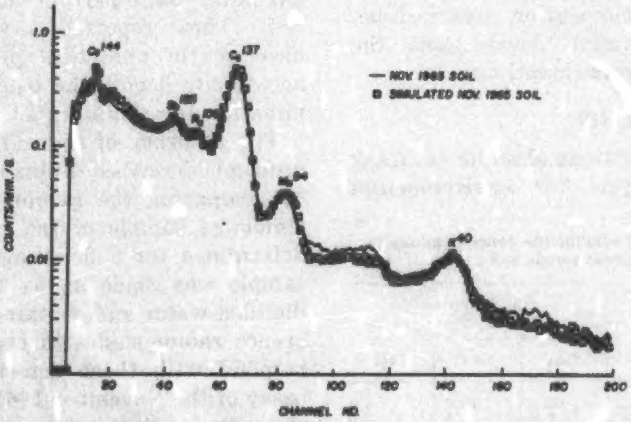

Figure 4. Comparison of gamma-ray spectra of simulated and field soil samples

Discussion

During the course of this soil radioassay program, it was found that the levels of artificial radioactivity found in Picatinny Arsenal soil samples were considerably higher than in some random samples collected from outside of the military reservation. It was suspected that this was due to the particular nature and composition of the soil in the arbitrarily selected Arsenal site. To test this hypothesis, on October 14, 1965, in addition to the usual sample, three additional soils were obtained from locations within a 15-mile radius of Picatinny Arsenal. Again, each sample came from a primarily deciduous woods area and the soil was taken from the top 2 inches of surface. In addition to radioassay, the ash content of each sample was also determined. These results are shown in table 2 and are presented in order of increasing ash content.

Table 2. Radioassay of four different northern New Jersey woods soil samples collected on October 14, 1965

Location	Ash content (percent)	Concentration (pCi/g)				
		^{144}Ce	^{125}Sb	^{106}Ru	^{137}Cs	^{54}Mn
Picatinny Arsenal	22.0	27.3	7.8	14.3	37.1	2.7
Morristown	80.4	6.2	2.4	4.5	6.4	1.1
Shongum Lake	84.4	2.6	1.3	2.0	3.1	0.6
Newton	92.3	2.6	1.1	1.6	1.5	0.6

The measured radionuclide concentrations are, in general, inversely related to the ash content, or conversely, the higher the content of organic matter in the soil, the higher is the concentration of each artificial radionuclide. The Picatinny Arsenal sample, which has a considerably higher organic content contains the highest concentration of these radionuclides.

The higher concentrations of fallout radionuclides in organically-rich soils are attributed partially to the original presence of the radioactivity in the vegetation from which the organic matter is derived. Another factor, perhaps of equal or greater importance, is a high retention capacity for radionuclides which settle directly on this type of soil. Organically-rich soils are known to have a higher exchange capacity for most cations than sandy soils (*5*). Once adsorbed in the complex organic structure, the radionuclides can be expected to become relatively fixed and not as easily washed out by rainfall. This is supported by experiments which have shown that the uptake of fallout radionuclides by plants was much less from organically-rich soils than from sandy soils (*6*).

The unusually high organic content of the Picatinny Arsenal woods soil is related to the general geology of the immediate region. The site is characterized by many rock outcroppings which extend over large areas dating back to the most recent glacial activity. As a result, overburden throughout the region is either non-existent or very thin and there is little or no soil. Woods soil in this locality is therefore composed mostly of organic matter derived from fallen vegetation.

There is little published information on soil radionuclide measurements from other parts of the United States for this period, which would allow for a direct comparison with the data reported here. Wykes (*7*) has reported cesium–137 concentrations in soil collected in the dairyland region of Elk River, Minnesota. Average annual values for 1964 and 1965 are given as 1.4 and 1.5 pCi/g, respectively, and the soil samples are characterized as essentially sandy in composition. These values are similar to those for Newton and Shongum Lake, New Jersey. In contrast, the average annual values for cesium–137 in Picatinny Arsenal woods soil (table 1) were 28.9 and 23.2 pCi/g for these 2 years.

Acknowledgement

The author is grateful to C. M. Starrett, R. I. Isakower and P. J. Kemmey for their assistance with the computer programs for the radionuclide analyses.

REFERENCES

(*1*) HELF, S. Environmental radioactivity measurements in the Picatinny Arsenal area, 1963–1966. Picatinny Arsenal Technical Report No. 3516 (March 1967).

(*2*) HAGEE, G. R., G. J. KARCHES and A. S. GOLDIN. Determination of I–131, Cs–137, and Ba-140 in fluid milk by gamma spectroscopy. Talanta 5:36–43 (1960).

(*3*) BLACKBURN, J. A. Computer program for multicomponent spectrum analysis using least-squares method. Anal Chem 37:1000–1003 (1965).

(*4*) CAMBRAY, R. S., E. M. R. FISHER, G. S. SPICER, C. G. WALLACE and T. J. WEBBER. Radioactive fall-out in air and rain: results to the middle of 1964. Atomic Energy Research Establishment (U.K.) Report No. 4687 (1964).

(*5*) EISENBUD, M. Environmental Radioactivity, Chapter 4. McGraw-Hill Book Co., Inc., New York, N.Y. (1963).

(*6*) GULYAKIN, I. V. and A. W. KOROVKINA. Organic matter, soil composition and fission uptake. Compost Sci 2:12–13 (1963).

(*7*) WYKES, E. R. Cesium–137 and strontium–90 in a dairyland environment. Radiol Health Data Rep 7:545–547 (September 1966).

Cesium–137 Burdens of Some Cincinnati Residents, July 1964–March 1967

H. E. Kolde [1]

The whole-body counter of the National Center for Radiological Health at Cincinnati, Ohio was employed to monitor 190 residents of the Cincinnati metropolitan area during the period July 1964 through March 1967. The cesium–137 values obtained have been compiled for this report to provide current data for comparison with other populations exposed to this radionuclide in their environment.

The majority of the subjects were local residents for at least the past 5 years and consisted of Public Health Service personnel, employees of an Atomic Energy Commission contractor, and dietitians from local hospitals. They ranged in age from 16 to 57 years but most of them were 25 to 40 years old. Data for individuals that showed burdens of radionuclides other than cesium–137 and potassium–40 or with frequent occupational exposure to cesium–137 were excluded since they were from a different "population." Approximately 30 of the subjects were monitored on three or more occasions during the period. Results for any person monitored more than once in any quarter were averaged and entered as a single observation.

The whole-body counter consists basically of an 8- by 4-inch NaI (T1) detector with a NaI light pipe, a multichannel analyzer, and an 8- by 12-foot steel room with a 5-inch wall thickness (*1*). Subject geometry and detector location conform to the tilted chair configuration defined by the International Atomic Energy Agency (IAEA) (*2*). The system has been standardized for potassium–40 measurements by the *in vivo* technique of administering potassium–42 intravenously to 10 persons ranging in weight from 60 to 129 kg. The cesium–137 calibrations were performed with phantom humans constructed of various parcels of sugar loaded with portions of an absolutely standardized solution. The adequacy of the phantom designs was determined by loading them with potassium–42 or potassium–40 and comparing the results to those derived *in vivo*. The potassium–42 experiment and work with the phantoms loaded with cesium–137 have shown that the counting efficiency of this system decreased linearly with increasing body weight. The interference factors for subtracting potassium–40 contributions from the cesium–137 portion of the human gamma-ray spectrum were determined by the potassium–42 experiment.

The overall random error for individual cesium–137 observations varied commonly from ±7 to ±11 percent at the 95-percent confidence level for 1964 observations to ±10 to ±35 percent for males and ±20 to ±60 percent for females in early 1967. Precision of cesium–137 measurement is calculated on the basis of errors propagated by the subject and background counting rates, potassium–40 spectral interference, and the uncertainty in fitting the cesium–137 efficiency curve. Subject counting duration is 30 minutes. The minimum detectable radioactivity is 0.5 nCi at the 95-percent confidence level for a 30-minute measurement of a 70-kg individual with a potassium content of 154 grams.

Table 1 presents the results of the cesium–137 measurements averaged on a quarterly basis separately for the two sexes. It should be noted that these measurements were obtained incidental to performance of other studies, and information is unfortunately sparse during several intervals of experimental usage of the counter. Downward trends in cesium–137 burdens, however, are apparent, as anticipated from the suspension of nuclear testing in the atmosphere by the United States, Russia, and Great Britain. The levels in males in the first quarter of 1967 are approximately one-third of those observed in the third quarter of 1964. The burdens in females declined to approximately 25 percent of original values. The dis-

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Table 1. Quarterly average cesium-137 contents of metropolitan Cincinnati residents[1] July 1964–March 1967

Quarter and year	Individuals per quarter [a]	Average weight (kg)	Average potassium concentration (g/kg)	Average cesium-137 concentration		Average body burden (nCi)
				(pCi/kg)	(pCi/g K)	
Male						
3rd/64	12	77.4	2.1	[b] 250 ± 95	120	19
4th/64	14	78.1	2.2	240 ± 100	110	19
1st/65	2	84.9	2.2	240 ± 60	100	21
2nd/65	8	82.4	2.2	200 ± 90	90	17
3rd/65	7	83.4	2.0	190 ± 50	90	16
4th/65	30	79.8	2.0	170 ± 75	85	13
1st/66	57	79.9	2.0	140 ± 60	70	11
2nd/66	60	77.5	2.0	130 ± 70	60	9
3rd/66	14	78.6	2.1	110 ± 60	60	9
4th/66	17	77.0	2.1	95 ± 55	45	7
1st/67	13	81.5	2.0	85 ± 35	45	7
Female						
3rd/64	9	65.1	1.7	170 ± 95	100	11
4th/64	10	62.6	1.6	140 ± 80	85	9
1st/65	5	58.7	1.8	140 ± 50	80	8
2nd/65	4	57.3	1.8	120 ± 45	70	7
3rd/65	6	61.3	1.6	110 ± 75	75	7
4th/65	12	61.1	1.7	80 ± 60	45	5
1st/66	16	63.7	1.7	80 ± 65	45	5
2nd/66	16	62.2	1.6	60 ± 55	40	4
3rd/66	13	64.4	1.6	50 ± 40	30	3
4th/66	10	66.4	1.6	35 ± 45	20	2
1st/67	14	65.2	1.6	40 ± 35	25	3

[a] Results were averaged for each individual counted more than once per quarter and denoted as one observation in that quarter.

[b] Variation of individual results at 2 standard deviations.

appearance of cesium–137 radioactivity in whole-body spectra was noted for the first time during this monitoring in the measurement of two female subjects during December 1966.

To demonstrate the decrease in cesium–137 content of a single individual, results were compiled for the subject most frequently monitored (table 2). The subject was a male in good health, 35 to 37 years of age, who varied in weight by less than ±3 percent. His average potassium concentration was 2.1 g/kg and his dietary habits were relatively constant, although he reduced his milk consumption from slightly more than 1 quart per day to approximately 1 pint per day in June 1966. Cesium–137 burdens in this case decreased by a factor of 3.4.

REFERENCES

(*1*) BRANSON, B. M., G. J. KARCHES, H. E. KOLDE, R. K. STOMS, B. KAHN, and C. P. STRAUB. High sensitivity low-background gamma spectrometry system-design through initial results. Health Physics 11:1083 (1965).

(*2*) INTERNATIONAL ATOMIC ENERGY AGENCY. Directory of whole-body radioactivity monitors. IAEA, Vienna (1964).

Table 2. Quarterly average cesium-137 contents of one male adult, July 1964–March 1967

Quarter and year	Observations	Average weight (kg)	Average potassium concentration (g/kg)	Average concentration		Average burden (nCi)	Average cesium-137 analytical measurement error (percent)
				(pCi/kg)	(pCi/g K)		
3rd/64	2	71.7	2.1	[a] 335 ±30	160	24	[b] ± 7
4th/64	2	74.1	2.1	300 ±35	140	22	± 7
1st/65	2	74.5	2.2	285 ±35	120	21	± 7
2nd/65	5	72.6	2.3	260 ±20	110	19	± 7
3rd/65	2	71.2	2.0	195 ± 0	95	14	± 9
4th/65	3	72.0	2.0	160 ±30	75	12	±10
1st/66	6	72.5	2.1	145 ±30	65	10	±10
2nd/66	7	73.4	2.2	145 ±25	65	10	±11
3rd/66	6	73.4	2.1	120 ± 5	55	9	±12
4th/66	9	73.2	2.1	100 ±35	45	8	±15
1st/67	8	74.5	2.0	95 ±25	40	7	±14

[a] Variation of individual results at 2 standard deviations.

[b] Error given at 2 standard deviations.

Plutonium Concentrations in Ground Level Air and Changes in Plutonium-238 To Plutonium-239 Ratios

B. Shleien and *P.J. Magno*[1]

Information on airborne plutonium isotopes is of interest in evaluating the potential health hazard of these material and in investigating the transport processes involved. A unique injection of plutonium–238 into the atmosphere took place in April 1964 when 17 kilocuries of this isotope contained in a SNAP–9A power source burned up south of the equator off the coast of Africa (*1*). Analysis of ground level airborne particulate samples for plutonium isotopes has been performed at the Northeastern Radiological Health Laboratory since May 1965. Airborne concentrations for 1965 have been presented elsewhere (*2*). Data for January 1966 to February 1967 are presented in this paper.

Monthly composite particulate samples representing 12,000 m^3 of air are collected on 8- by 10-inch membrane filters (pore size 0.8μ) at a height of one meter above the ground. The samples are wet ashed with a mixture of nitric and perchloric acids. Plutonium–236 tracer is added, the plutonium reduced to the +3 state and coprecipitated with lanthanum fluoride. The fluoride precipitate is then converted to hydroxide, dissolved in 7.2 *M* nitric acid and the plutonium oxidized to the +4 state.

Plutonium is sorbed from the solution on an anion exchange resin in the nitrate form. The resin is washed with additional 7.2 *M* nitric acid, and then with 9 *M* hydrochloric acid. The plutonium is eluted from the resin with a mixture of 0.36 *M* hydrochloric acid and 0.01 *M* hydrofluoric acid, and finally electroplated onto a stainless-steel planchet from a sulfuric acid-ammonium sulfate electrolyte.

Samples are usually counted in an alpha-particle spectrometer for at least 1,000 minutes with a silicon surface barrier detector of 450 mm^2 surface area. Counting efficiency is approximately 31 percent. Chemical yield is determined by the recovery of the plutonium–236 tracer.

Concentrations of plutonium–239[2] and plutonium–238 in ground level airborne particulates at Winchester, Mass. for the period of January 1966 to February 1967 are presented in table 1. The mean concentration for plutonium–239 was 0.068 fCi/m^3 and the mean concentration for plutonium–238 was 0.006 fCi/m^3. The mean concentration of plutonium–239 decreased by one-half from the mean previously reported (May 1965 to April 1966) (*2*), while the mean plutonium–238 concentration remained relatively constant. A change in the plutonium–238 to plutonium–239 ratio becomes fairly evident in mid-1966. The change in the ratio indicates a new source of plutonium–238 than that which was previously present. A probable conclusion is that plutonium–238 from the SNAP–9A burn-up has reached ground level in the Northern Hemisphere.

The expected spring rise in plutonium–239 concentration was evident after January and reached a maximum in May 1966. The magnitude of measurement errors in plutonium–238 analysis does not permit firm conclusions concerning a spring rise for this nuclide, although a general increase in plutonium–238 concentration appears to have been present during the spring months.

Using a plutonium–238 to plutonium–239 ratio of 0.04 for weapons debris, an estimate of plutonium–238 from SNAP–9A can be made and is presented in table 1. The ratio of plutonium–238 to plutonium–239 from September

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[2] The energies of the alpha particles from plutonium–239 and plutonium–240 are not sufficiently different to be separated by the alpha-particle spectrometry method employed. Therefore, when plutonium–239 is referred to in this report, it is meant to represent the sum of the activities of plutonium–239 and plutonium–240.

1966 on appears to have been statistically similar. Although errors are large, an increase in SNAP-9A plutonium-238 is indicated. A similar increase has been reported in Italy (*3*). The estimates for plutonium-238 because of the SNAP-9A burn-up agree with those estimated by the Health and Safety Laboratory (HASL) (*4*). The data presented above appears to be indicative of an intrusion of plutonium-238 into ground-level air in the Northern Hemisphere from the burn-up of SNAP-9A.

REFERENCES

(*1*) HARLEY, J. H. Possible Pu^{238} distribution from a satellite failure. HASL-149:138 (1965).

(*2*) MAGNO, P. J., P. E. KAUFFMAN, and B. SHLEIEN. Plutonium in environmental and biological media. U.S. Public Health Service, National Center for Radiological Health, Winchester, Mass. (1966), in press, Health Physics.

(*3*) De BORTALE, M. and P. GAGLIONE. Increasing plutonium-238/plutonium-239 ratio in surface air at ISPRA, Italy. HASL-174:1-6 (January 1967).

(*4*) VOLCHOK, H. L. The anticipated distribution of Cd-109 and Pu-238 (from SNAP-9A) based upon the Rh-102 tracer experience. HASL-165:312 (January 1966).

Table I. Plutonium-239 and plutonium-238 in airborne particulates at ground level at Winchester, Mass., 1966-1967

Month	Radionuclide concentration (fCi/m³+E) [a]		Ratio ±E [a] ^{238}Pu: ^{239}Pu	Estimated [b] ^{238}Pu from SNAP-9A (fCi/m³)
	Plutonium-239	Plutonium-238		
1966				
January	0.047 ±0.010	0.001 ±0.008	0.02 ±0.04	(c)
February	0.071 ±0.010	0.006 ±0.003	0.07 ±0.04	0.003 ±0.003
March	0.080 ±0.012	0.003 ±0.002	0.03 ±0.02	(c)
April	0.131 ±0.016	0.005 ±0.003	0.04 ±0.02	0.000 ±0.003
May	0.307 ±0.030	0.012 ±0.004	0.06 ±0.02	0.004 ±0.005
June	0.130 ±0.014	0.008 ±0.003	0.06 ±0.02	0.003 ±0.004
July	0.073 ±0.010	0.003 ±0.003	0.04 ±0.04	0.000 ±0.003
August	0.050 ±0.008	0.005 ±0.002	0.10 ±0.04	0.003 ±0.003
September	0.035 ±0.008	0.004 ±0.003	0.11 ±0.09	0.003 ±0.003
October	0.030 ±0.008	0.005 ±0.003	0.25 ±0.15	0.004 ±0.003
November	0.026 ±0.006	0.011 ±0.004	0.44 ±0.19	0.010 ±0.003
December	0.018 ±0.005	0.003 ±0.003	0.17 ±0.17	0.002 ±0.003
1967				
January	0.022 ±0.006	0.005 ±0.003	0.23 ±0.15	0.004 ±0.003
February	0.027 ±0.006	0.007 ±0.003	0.26 ±0.12	0.006 ±0.003

[a] Error at 95-percent confidence level due to radiochemical and counting errors.

[b] Based on mean plutonium-238 to plutonium-239 ratio May 1965 to July 1966 of 0.040 ±0.02.

[c] The estimated plutonium-238 from SNAP-9A for these months, based on a mean plutonium-238 to plutonium-239 ratio of 0.04 ±0.02 result in negative value which should be interpreted as 0.00 fCi/m³ from SNAP-9A. The actual results obtained are: January 1966, 0.001 ±0.002 fCi/m³; March 1966, 0.001 ±0.006 fCi/m³.

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Reported Nuclear Detonations, August 1967

During August 1967, three U.S. underground nuclear tests of low yield (less than 20 kilotons TNT equivalent) were announced by the Atomic Energy Commission. These tests occurred on August 10, August 18, and August 31 at the Nevada Test Site.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

A PROPOSED RADIOACTIVITY CONCENTRATION GUIDE FOR SHELLFISH. *C. L. Weaver. Radiological Health Data and Reports, Vol. 8, September 1967, pp. 491–494.*

The recommendations of the International Commission on Radiological Protection (ICRP), the National Committee on Radiation Protection (NRCP), and the Federal Radiation Council (FRC) have been applied in deriving proposed guides for radioactivity in shellfish. FRC Report No. 1 presents basic exposure criteria, FRC Report No. 2 presents intake guides for strontium–89, strontium–90, iodine–131, and radium–226, and NCRP and ICRP provide data on the maximum permissible concentrations of radionuclides in water. The proposed guide was assembled by the National Center for Radiological Health in collaboration with the Water Supply and Sea Resources Program of the National Center for Urban and Industrial Health, Public Health Service.

KEY WORDS: aquatic food chains, intake guides, iodine–131, radioactive wastes, radium–226, shellfish, strontium–89, strontium–90.

RADIOACTIVITY IN THE MEXICAN ENVIRONMENT. *R. M. Nulman and M. V. Barets. Radiological Health Data and Reports, Vol. 8, September 1967, pp. 495–501.*

The Comisión Nacional de Energía Nuclear in Mexico operates surveillance networks monitoring radioactivity in airborne particulates, particulates in fallout and precipitation, drinking water, milk, food, and sea water. Methods of analysis and the resultant data for 1965 and 1966 are presented. This surveillance program was instituted to provide a general picture of the radioactivity levels in the Mexican environment, protection for the Mexican people from overdoses of radiation, and information for the handling of legal claims that may arise against the Nuclear Center of Mexico (now under construction).

KEY WORDS: airborne particulates, drinking water, fallout, food, Mexico, milk, Nuclear Center of Mexico, precipitation, sea water, Surveillance Networks.

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